From:	SEEDS Joshua <SEEDS.Joshua@deq.state.or.us>
Sent time:	01/07/2014 02:16:00 PM
To:	Leinenbach, Peter; Kubo, Teresa; Henning, Alan; Powers, David
Subject:	RE: Forestry effects at the WRC paired watershed studies
Attachments:	Forest Roads Management Approach_draft_02-05-2013.docx Integrated Road Management Outline_draft_01-17-2013.docx

Forest Roads document from MidCoast TMDL efforts attached. As I mentioned, this is halfway through a major re-organization/revision, but I think the pieces are all there. The first 11 pages are best organized include the road metrics I mentioned. Also attached in the Integration Document that describes the overall road approach across land uses (forestry roads, ag roads, public roads). We were using this as part of an approach going beyond forest roads to include impacts of ag roads and public roads.

Thanks,
Josh

From: Leinenbach, Peter [mailto:Leinenbach.Peter@epa.gov]
Sent: Tuesday, January 07, 2014 12:59 PM
To: SEEDS Joshua; Kubo, Teresa; Henning, Alan; Powers, David
Subject: RE: Forestry effects at the WRC paired watershed studies

Thanks Josh

From: SEEDS Joshua [mailto:SEEDS.Joshua@deq.state.or.us]
Sent: Tuesday, January 07, 2014 12:53 PM
To: Leinenbach, Peter; Kubo, Teresa; Henning, Alan; Powers, David
Cc: SEEDS Joshua
Subject: Forestry effects at the WRC paired watershed studies

Pete et al,
Attached is the email I sent to DEQ staff and managers after last April's Paired Watershed Study Symposium, describing claims I heard by some presenters that do not seem to be scientifically grounded. Also attached are my meeting notes for November's "Policy Workshop". The basic line of argument is that the fish seem to be fine in the very short-term, so there are no problems. Within my meeting notes are a mix of my recollections of the presentations themselves along with notations and issues that I noticed. I have tried to mark my notes using brackets and other sorts of labels. Both of these events deal with the three ongoing paired watershed studies in Oregon (Hinkle Creek, Alsea Revisited, Trask River).

This information is FYI only for you all. I don't want this widely spread at this point, as the means and timing of publically disagreeing with the opinion of some of the assertions being made is very important. There will be a more detailed assessment of DEQ's take on the science from these paired watershed studies forthcoming; that will be something which is more widely distributed. Any help that you are able to give in assembling the evidence (published studies or new analysis) that shines light on unfounded claims being made would be most appreciated.

Let me know if you have any questions or comments.

Thanks,
Josh

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Middle Fork Payette River
GRAIP Watershed Assessment
USDA Forest Service, Boise National Forest

September 2013

Scott Bergendorf[1], Brian Anderson[1], Tom Black[2], Megan Jenkins[1], John Thornton[1] and Charles Luce[2]

	[1]USDA Forest Service Boise National Forest 1249 S. Vinnell Wy. Suite 200 Boise, Idaho 83709	[2]USDA Forest Service Rocky Mountain Research Station 322 E. Front St. Suite 401 Boise, Idaho 83702	Produced with funding from: EPA United States Environmental Protection Agency

Middle Fork Payette River Road Inventory (GRAIP) Report
Boise National Forest

Acknowledgements

Through interagency agreement DW-12-92273301, the U.S. Environmental Protection Agency (USEPA) provided funding for the field inventory and data analysis in order to conduct GRAIP analysis for roads and streams within the Middle Fork Payette River sub-basin. Without this funding, the project would not have been possible. The views expressed in this document do not necessarily reflect the views of the USEPA.
The following individuals were field crew members for the Boise National Forest who were critical to the progress of this road inventory and are acknowledged and appreciated for their contributions to the successful completion of this project:

Chase Fly
Nathaniel Bogie
Curtis Martin
Blaise Bernal
Ernesto Matal Sol
Michelle Fast
Rumika Chaudhry
James Bitzenburg
Terry Dever
Tyrel Trainor
Matt Taylor

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Executive Summary

The US EPA began funding a site-specific road sediment inventory in 2009 within the Middle Fork Payette River Sub basin to assist with the implementation plan to meet water quality obligations associated with an assigned Total Maximum Daily Load (TMDL) for sediment (State of Idaho 1998 and 2003). Over 580 miles of roads were mapped and surveyed by field crews from 2009 to 2011. The completed portion of the survey accounts for more than 95% of National Forest System (NFS) roads. In 2011, field crews focused on surveying all accessible state, county, private, or other non-NFS jurisdictional roads. Approximately 90% of state roads and 15% of private roads were collected during this year. Overall, about 70% of the sub basin has been surveyed. This inventory quantified the extent and location of sediment contributions from roads to streams, using the Geomorphic Road Analysis and Inventory Package (GRAIP, Black and others 2012, Cissel and others 2012, Prasad et al. 2007, http://www.fs.fed.us/GRAIP). This robust suite of inventory and analysis tools evaluates the following impacts and risks of roads: road-stream hydrologic connectivity, fine sediment production and delivery, upstream sediment accumulation, drain point condition, stream crossing failure risk, gully initiation risk, and shallow landslide risk.
The Middle Fork Payette River Sub basin is a 339 mi^2 4th field hydrologic unit within the Payette River watershed in central Idaho. The Middle Fork Payette River Sub basin contains four 5th field watersheds and twelve 6th field sub watersheds. The Boise National Forest (BNF) collaborated with the Rocky Mountain Research Station (RMRS) to complete a GRAIP road inventory in the Middle Fork Payette River Sub basin and develop risk profiles for the surveyed roads to assess impacts and risks to key watershed processes. A summary of predicted risks is displayed in Table 1.
Field crews mapped and collected data on a total of 583 miles of roads within the Middle Fork Payette River Sub basin, suggesting a road density of 1.7 mi/mi^2 (actual road density is assumed to be higher as 100% of roads were not surveyed during this inventory). While the majority of NFS and State roads in the sub basin are included in these 583 miles of surveyed road length, it is estimated that there may be up to 100 more miles of county, private, and unmapped Forest roads that remain unsurveyed (increasing road density to approximately 2 mi/mi^2).
In many cases, old roads overgrown with brush and trees were encountered by crews in the field but could not be located on any available map or GIS layer. It was found that,

throughout the sub basin, many areas exist that have undergone past timber management utilizing road based yarding systems and not all road prisms are accounted for. There also exist many geometrical discrepancies among existing road GIS layers and the shapes of roads as physically mapped in the field and visualized on areal mapping.

Road-stream hydrologic connectivity was calculated to be 113 miles (19% of all road length surveyed). The total amount of fine sediment from roads accumulating in the Middle Fork Payette River and its tributaries was 790.1 tons/yr, which accounts for 20% of all sediment produced on surveyed roads. The predicted sediment delivery rate from roads of 2.3 tons/mi^2/yr. suggests a 4% increase above the natural reference sediment erosion rate as predicted by the BOISED model (Reinig et al. 1991).

Approximately 10% of road drainage features were recorded to be in poor condition or in need of maintenance. The risk of stream crossings becoming plugged was evaluated based on a stream blocking index (SBI) where 1 indicates virtually no risk and 4 indicates high risk. The average SBI for stream crossings in this survey was 1.6. A total of 32% of all stream crossings have diversion potential, suggesting a moderate to high risk of stream water flowing down the road prism and hillslope if the pipe is blocked. An estimate of 49,131 yd$^{3\ \mathrm{was}}$ made of fill volume at risk at stream crossings.

Slope stability data, which includes the frequency and attributes of observed landslides and gullies, is used to calculate gully initiation risk and landslide potential resulting from roads. 119 hillslope failures were observed and recorded in the survey. 199 gullies were observed of which 187 were determined to be related to excessive road drainage. Surveys of the gully volume determined that 13,578 yd^3 have been eroded at these location over the time since construction. An Erosion Sensitivity Index (ESI) was calculated for the gullies and determined that the probability of gullying increased from about 1% to 6% when long road segments drained to steep unstable hillslopes.

Quality assurance measures were taken in order to ensure the integrity of the data collected. Field crews were trained on data collection methods by individuals considered experts in using the GRAIP inventory protocol. Quality assurance plots were surveyed by each crew and by an expert crew in order to ascertain relative precision and bias of data collected. Results suggest that the margin of error among data collected by the different crews was acceptable and that the data are considered usable for analysis. Crews were audited monthly during the survey of a road by an expert who corrected procedural mistakes in real time and provided additional training.

Taken collectively, inventory results indicate that several portions of the road network throughout the sub basin result in accelerated sedimentation and risks to aquatic ecosystems. Relative to road sediment production, sediment delivery is moderate to high on several roads (e.g. NFS roads 668 (Anderson Creek), 696 (Middle Fork Scriver Creek), and 698 (Middle Fork Payette River)), while the location (distance from waterways) of other roads makes them essentially benign in regard to sediment delivery. The granitic material in the area weathers to form a poorly cohesive soil and much of the road network does not have a resistant surfacing material. Each individual road has different use and management qualities associated with it and this presents various options to reduce road sediment delivery including road surfacing, drainage feature maintenance, and road decommissioning. GRAIP predictions can be used to address the needs of specific road segments and drain points in the design and implementation phases of future road restoration or road maintenance projects.

Table 1. Summary of GRAIP model risk predictions for the Scriver Creek sub-watershed.

Impact/Risk Type	GRAIP Prediction
Road-Stream Hydrologic Connectivity	113 miles, 19% of total road length
Fine Sediment Production (not delivered to stream)	3918.4 tons/year
Fine Sediment Delivery	790.1 tons/year, 20% of fine road sediment production
Upstream Sediment Accumulation	790.1 tons/year, 20% of fine road sediment production
Upstream Sediment Accumulation Rate	2.3 tons/mi^2/year, 4% over natural reference sediment erosion rate
Drain Point Problems	1653 drain points, 10% of all drain points.
Stream Crossing Failure Risk	
- plug potential	46 stream crossings with elevated risk, 9% of total
- fill at risk	49,131 cubic yards
- diversion potential	208 stream crossings, 32% of total
Gully Initiation Risk	174 of 199 observed gullies are road related and mobilize 18,191 tons occur at 1% of all drainpoints
Landslide Risk	76 of 119 landslides road related, with a volume of over 157,400 tons

Photo 1. Captions to photos on cover. *Top left:* Erosion on road draining to the Middle Fork Payette River above Tie Creek Campground. *Top right:* Jim Bitzenburg and fillslope erosion on road 662A. *Middle right: D*itch relief on a Private Driveway. *Bottom right:* Typical ditch relief in the Middle Fork Watershed with some fill erosion occurring.

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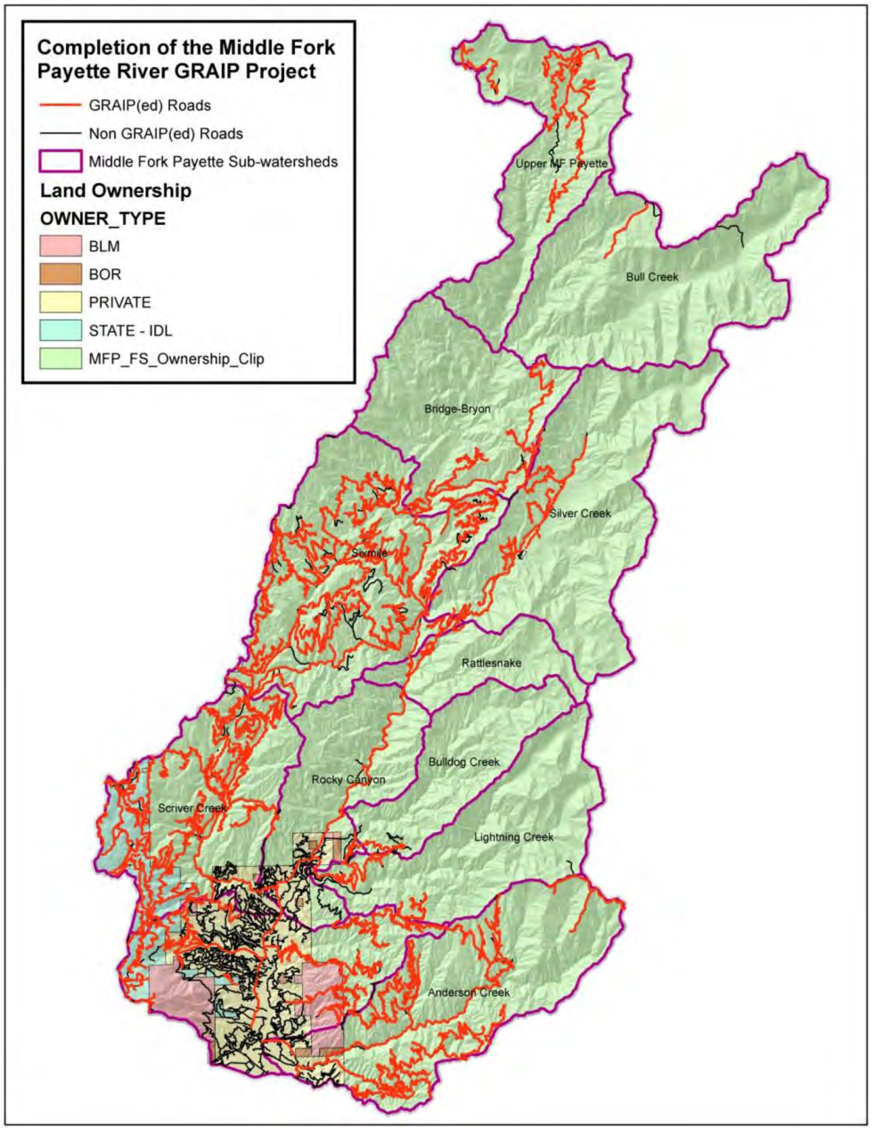
Figure 1. Map of the Middle Fork of the Payette Sub basin. Map Illustrates completed roads using the GRAIP survey method.



1.0 Methods

The Geomorphic Roads Analysis and Inventory Package (GRAIP) was used to inventory and model the risk profile of each of the road segments included in the study. The GRAIP system consists of a detailed, field-based road inventory protocol combined with a suite of geographic information system (GIS) models. The inventory is used to systematically describe the hydrology and condition of a road system using Geographic Positioning System (GPS) technology and automated data forms (Black and others 2012, Cissel and others 2012, and Luce 1999). The GIS models use these data to analyze road-stream hydrologic connectivity, fine sediment production and delivery, upstream sediment accumulation, stream sediment input, shallow landslide potential with and without road drainage, gully initiation risk, and the potential for and consequences of stream crossing failures. Detailed information about the performance and condition of the road drainage infrastructure is also supplied. The inventory was conducted in accordance with the Quality Assurance Project Plan (QAPP) developed in cooperation with the USEPA and the RMRS (Black et al. 2009).

2.0 Results

GRAIP inventory and modeling tools were used to characterize the following types of impacts and risks:

- Road-stream hydrologic connectivity
- Fine sediment production and delivery
- Upstream sediment accumulation
- Drain point condition
- Stream crossing failure risk
- Gully initiation risk
- Landslide risk

A brief summary of each impact or risk is included in this report with relevant tables, charts, graphics, and photos.

2.1 Road-stream Hydrologic Connectivity

Roads can intercept shallow groundwater and convert it to surface runoff, particularly in steep terrain, resulting in local hydrologic impacts when that water is discharged directly to channels (Wemple et al. 1996). Additional runoff is also produced from the compacted road surface. Basin-scale studies in the Oregon Cascades suggest that a high degree of integration between the road drainage system and the channel network can increase peak flows (Jones and Grant 1996).

GRAIP calculates the hydrologically-connected portion of the road using the field assessment of drain point connection and a road segment flow routing system. The flow path below each drain point is followed until evidence of overland flow ceases or the flow path reaches a channel. A total of 113 mi (182 km) out of the 583 mi (938 km) of surveyed roads in the Middle Fork Payette Watershed (19%) were hydrologically connected to a stream.

2.2 Fine Sediment Production & Delivery

Fine sediment production for a road segment (E) is estimated based on a base erosion rate and the properties of the road (Luce and Black 1999), as shown below. Sediment production is calculated for two unique flow paths on each road segment.

$$E = B \times L \times S \times V \times R$$

B is the base erosion rate[1] (kg/m/yr.)
L is the road length (m) contributing to the drain point
S is the slope (m/m) of the road segment
V is the vegetation cover factor for the flow path
R is the road surfacing factor

Delivery of eroded sediment to the channel network is determined by observations of each place that water leaves the road. Each of these drain points is classified as delivering or not delivering. No estimate of fractional delivery is made because there is insignificant hillslope sediment storage in locations where there is a clear connection to the channel under most circumstances. GRAIP identifies drain points at which sediment is delivered to a channel and estimates how much sediment is delivered to the channel at a given drain point in kilograms per year.

Drain Point Analysis

Highlighted GRAIP Predictions:

- Total sediment production (sediment eroded off of road surfaces) from all roads in the Middle Fork Payette Sub basin 3,918 tons/year
- Total eroded road sediment that reaches a stream equals 790 tons/year
  - 84% (663 tons/yr.) occurs on National Forest System roads, 16% (126 tons/yr.) occurs outside the Boise National Forest boundary on state or private lands
  - 20% of all sediment produced reaches a channel
  - 17% of effective road length delivers sediment to a channel
- 17,203 drain points were observed and recorded by field crews, 2,135 of which are actively delivering sediment to streams
  - 12% of drain points deliver 100% of all road sediment to streams
  - 1% of drain points deliver 50% of all road sediment to streams
  - 6% of drain points deliver 95% of all road sediment to streams

The road inventory information can answer many questions about the function and design of the road drainage system and how well the best management practices functioning. Table 2 and figure 2 show that ditch relief culverts are the most likely to deliver sediment to the stream, deliver the largest amount and connect the most road

[1] For this analysis, a base erosion rate of 17.8 kg/m/yr. of road direction per unit of slope was used. This figure is based on data collected from 2010 through 2012 at road sediment catchment basins located within the Middle Fork Payette River sub basin in the Lightning Creek sub-watershed. Further monitoring of sediment trapped by these basins over multiple years will help calibrate this figure over an extended period of time to account for variations in annual precipitation. See Appendix B for further details on the erosion plot study.

length proportionally. Stream crossings connect to the stream by definition, but in some cases broad based dips and non-engineered features are located at or adjacent to stream crossings. Diffusely drained roads are a common feature on low standard roads and they deliver only 4% of the total from roads.

Table 2. Summary of sediment production and delivery at drain points. Percent sediment delivery is the delivery divided by the total production. Percent connected length is the fraction of road length associated with that drain type that is connected to the channel.

Drain Type	Count	Total Sediment Production (T/yr)	Total Sediment Delivery (T/yr)	% Sediment Delivery	Connected Length (m)	% Connected Length[2]
Broad Based Dip	2,147	995.8	102.2	10%	155,603	11%
Diffuse Drain	4,551	369.2	13.0	4%	314,964	2%
Ditch Relief Culvert	2,486	705.0	266.2	38%	177,838	37%
Lead Off Ditch	137	39.4	9.7	24%	9,070	34%
Non-Engineered	1,810	634.6	118.4	19%	95,831	21%
Stream Crossing	657	131.9	131.9	100%	34,884	100%
Sump	133	48.6	0.0	0%	9,782	0%
Water bar	5,282	993.8	148.7	15%	140,491	13%
All Drains	**17,203**	**3918.4**	**790.1**	**20%**	**938,462**	**17%**

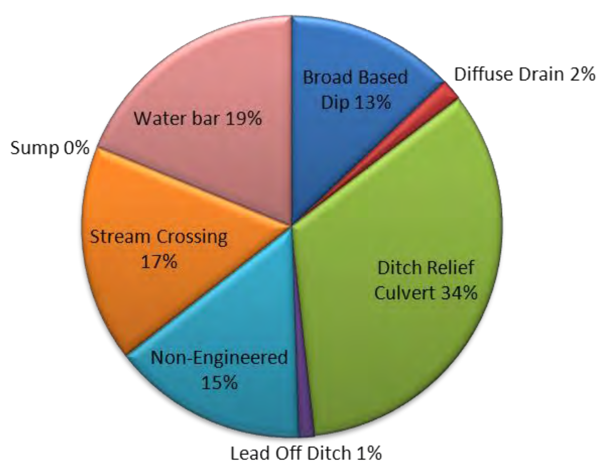


Figure 2. Distribution of total sediment delivered to a channel by drain type. Broad based dips and non-engineered drainage may occur at or near stream crossing locations, so the stream crossing delivery appears smaller than expected.

Table 3. Summary of drain point connectivity to streams and observed active sediment delivery at drain points.

Drain Type	Count	Drain Points Actively Delivering Sediment to Stream	% of Drain points Actively Delivering Sediment to Stream
Broad Based Dip	2,147	218	10%
Diffuse Drain	4,551	107	2%
Ditch Relief Culvert	2,486	815	33%
Lead Off Ditch	137	39	28%
Non-Engineered	1,810	340	19%
Stream Crossing	657	657	100%
Sump	133	0	0%
Water bar	5,282	469	9%
All Drains	17,203	2,135	12%

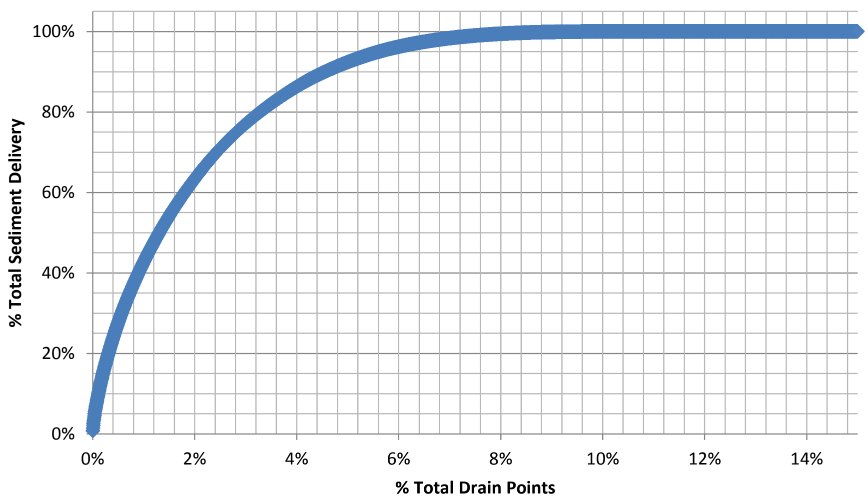


Figure 3. Percentage of the total amount of fine sediment delivered to a stream channel explained by the percentage of the total quantity of drain points.

Areas of High Sediment Delivery to Streams

Highlighted GRAIP Predictions:

Middle Fork Payette River Road Inventory (GRAIP) Report
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- Most sediment delivery from roads to streams is occurring on Maintenance Level 2 and above roads
  - Much of the road-stream connectivity takes place where roads run parallel to streams or within the immediate vicinity of a road/stream intersection
  - Level 1 roads generally appear to be low-impact
- Roads with excessive sediment delivery include:
  - NFS road 698 between the Sixmile Road Bridge (Jnct. 698 and 670) and Boiling Springs.
  - NFS roads 668 and 669 in the Anderson Creek drainage.
  - NFS road 696 in the Scriver Creek drainage.

Photo 2. FR 696 alongside West Fork Scriver Creek has frequent road-stream connectivity and high rates of road surface erosion.

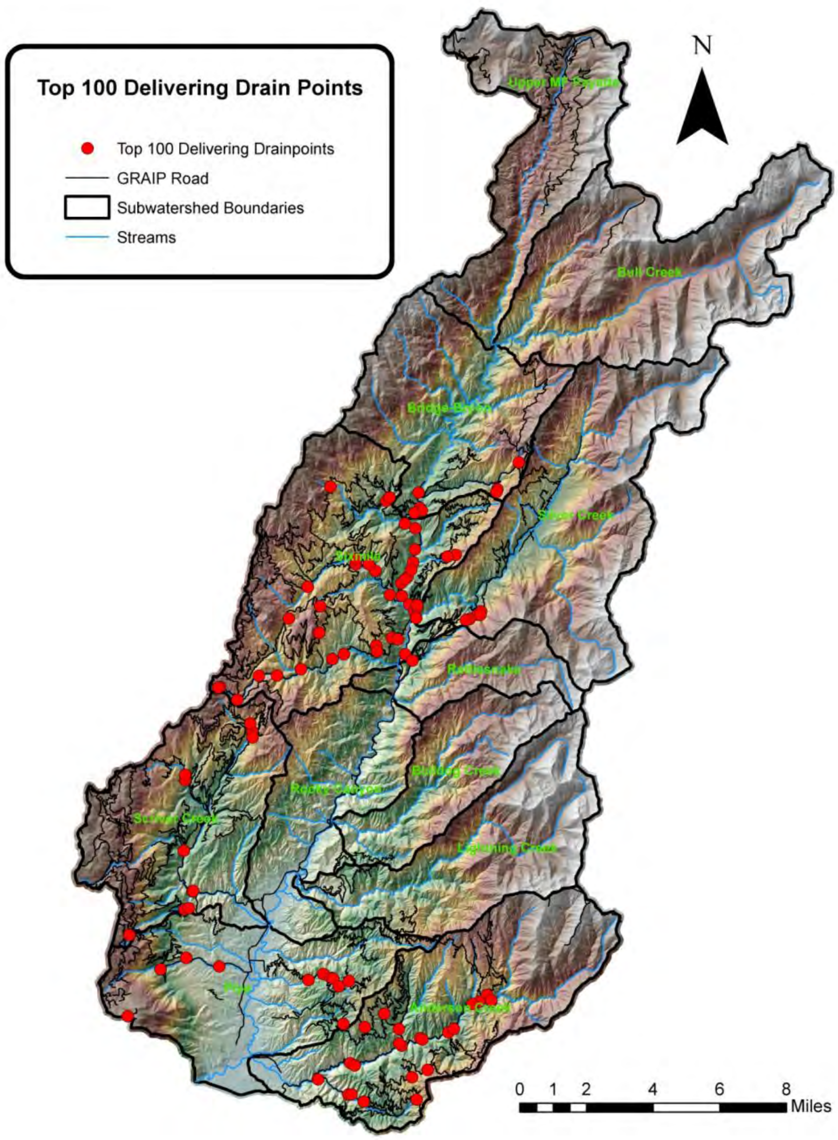
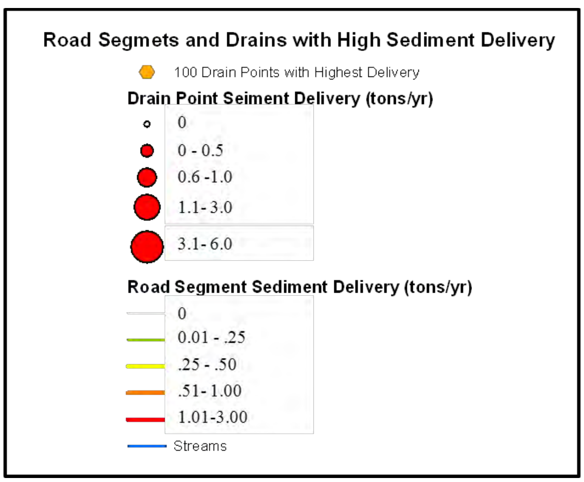


Figure 4. Map of top 100 drain points in terms of highest annual sediment delivery are emphasized**.**

Table 4. Fine sediment delivery values for road segments displayed in Figure 4 including percentage of total annual sediment delivery for the entire sub basin.

Figure 4 Map	Delivering Drain Point Count	% of Total Delivering Drain Points	Length of road Delivering (mi)	% of total Delivering Road Length	Sediment Delivery to Stream (ton/yr.)	% of Production that Delivers	% of Total Annual Sediment Delivery
A	42	13%	3.6	42%	35.1	51%	4%
B	127	17%	8.1	30%	76.3	35%	10%
C	70	15%	3.5	21%	27.5	33%	3%
Total	239	15%	15.2	29%	139.0	37%	18%

Figure 5. Maps of fine sediment delivery to channels by road segment and drain point. As indicated in the legend below, the road line is colored to indicate the predicted mass of fine sediment that is produced on the road and delivered to the channel. The size and color of the circle indicate the accumulated mass of sediment delivered through each drain point. All red circles indicate a drain point that is actively delivering sediment to streams while small white points represent a drain point not connected to the stream (see legend below). See Table 4 for length of sediment-contributing road segments and amount of fine sediment delivery for each displayed road.



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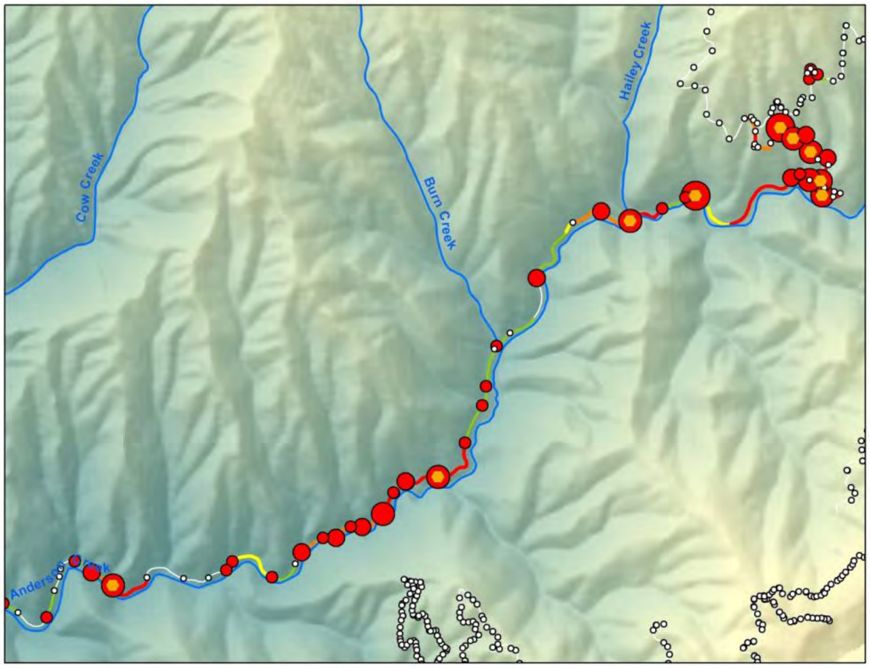
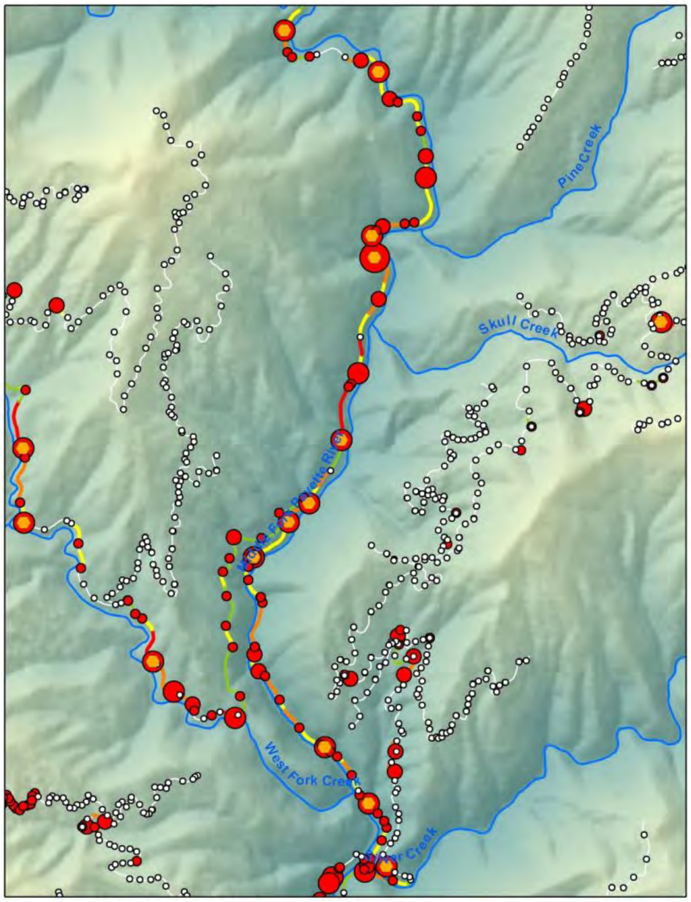


A) The portions of FR 668 displayed in this graphic are found along Anderson Creek. 9 of the top 100 delivering drain points are found in this area. The delivering drain points in this graphic are contributing 4% of all road sediment delivered to the Middle Fork Payette River.



B) Portion of the FR 698 between Silver Creek and Boiling Springs. This road follows the Middle Fork Payette River. 15 of the top 100 delivering drain points are found along this stretch. The delivering drain points are contributing 10% of all road sediment delivered to the Middle Fork Payette River.

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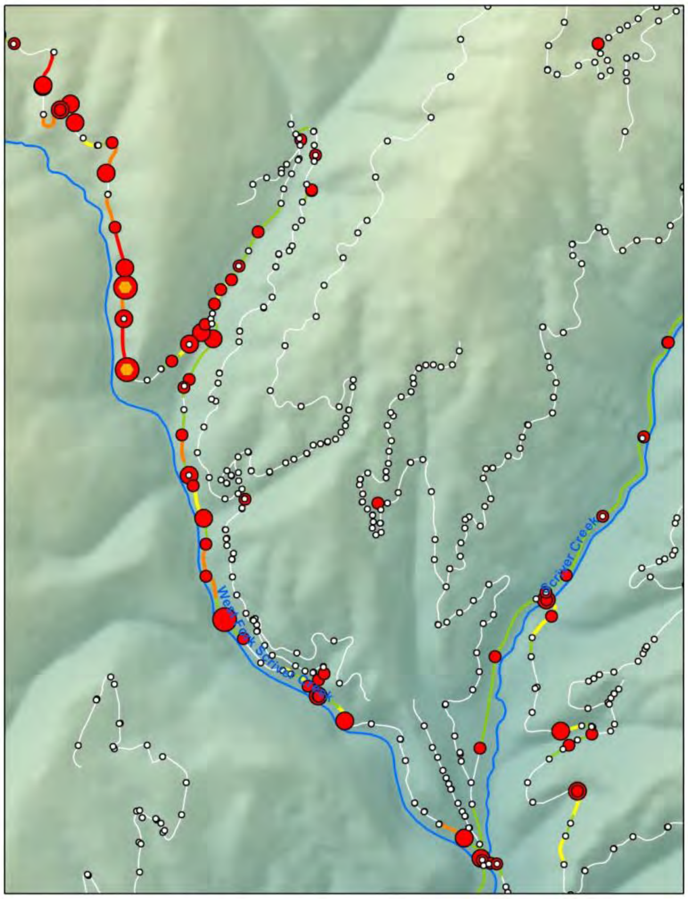

C) The portions of FR 696, FR 696A, FR 696A1, and FR 693Q shown in the below graphic are contributing about 3% of total sediment delivered in the Middle Fork Payette River. Decommissioning treatments have been appropriately arranged for these road segments as part of the Scriver Creek Integrated Restoration Project.

Road Segment Analysis
Road Segment Analysis
Highlighted GRAIP Predictions:

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- 8% of road length delivers 100% of road sediment to streams.
    - <2% of road length delivers 50% of sediment.
    - 5% of road length delivers 90% of sediment.
- 17% of recorded road segments deliver 100% of road sediment to streams.
    - 3% of road segments deliver 50% of sediment.
    - 10% of road segments deliver 90% of sediment.
- 64% of road surfaces were observed to be primarily made up of native material[2]
    - 7% had a crushed rock surface
    - 27% of road surfaces were dominated by vegetation, though were likely originally constructed with a native material surface.
- 49% of flow path length was recorded to have greater than 25% vegetation cover, dramatically reducing sediment production.

Photo 3. *Left:* Matt Taylor inspecting a gullied road surface on Rd 695F. *Top right:* Jim Bitzenburg surveying a waterbar road 695A. *Bottom right:* Saturated and rutted road surface of FR 695A**.**

[2] These numbers represent the road surface at the time GRAIP data was collected. Extensive road surfacing has been conducted along the 698 and 693 roads during 2010-2013.

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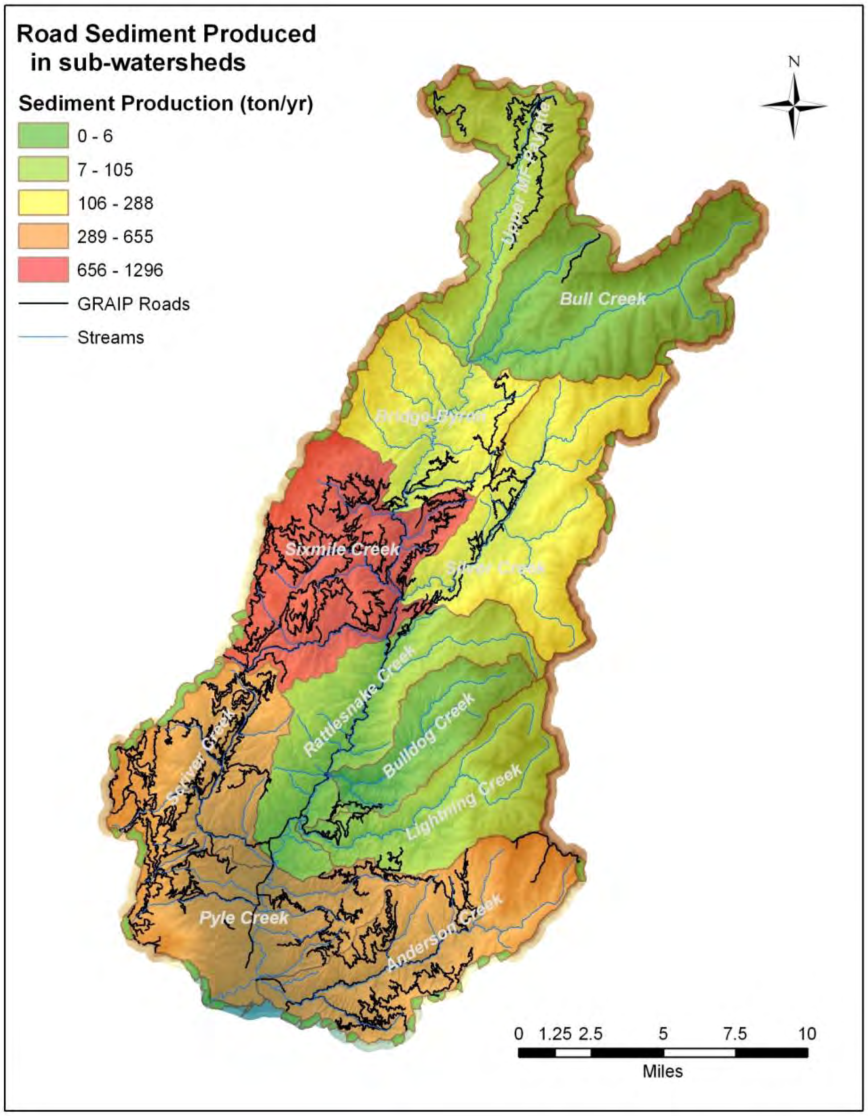
Figure 6. Middle Fork Payette River area map of sediment produced by erosion from the road surface by sub-watershed.



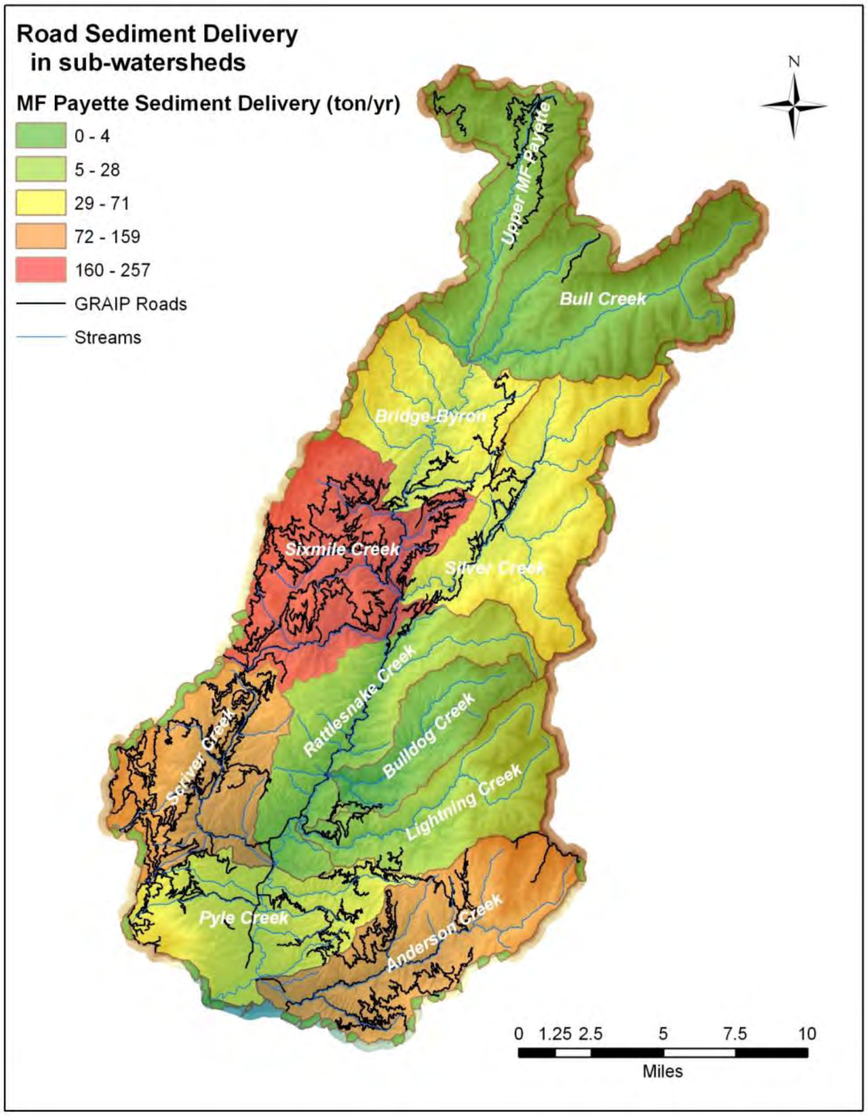


Figure 7. Middle Fork Payette River area map of sediment delivered to stream channel the road surface by sub-watershed.

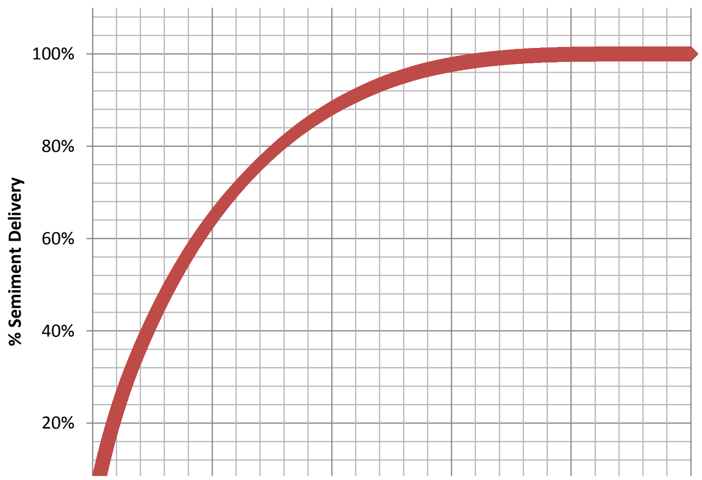


Figure 8. Percentage of the total amount of fine sediment delivered to a stream channel explained by the percentage of the total road length.

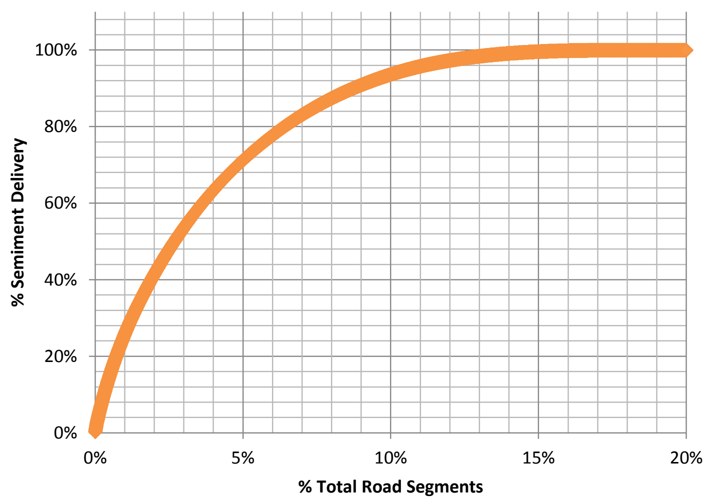


Figure 9. Percentage of the total amount of fine sediment delivered to a stream channel explained by the percentage of the total quantity of road segments.

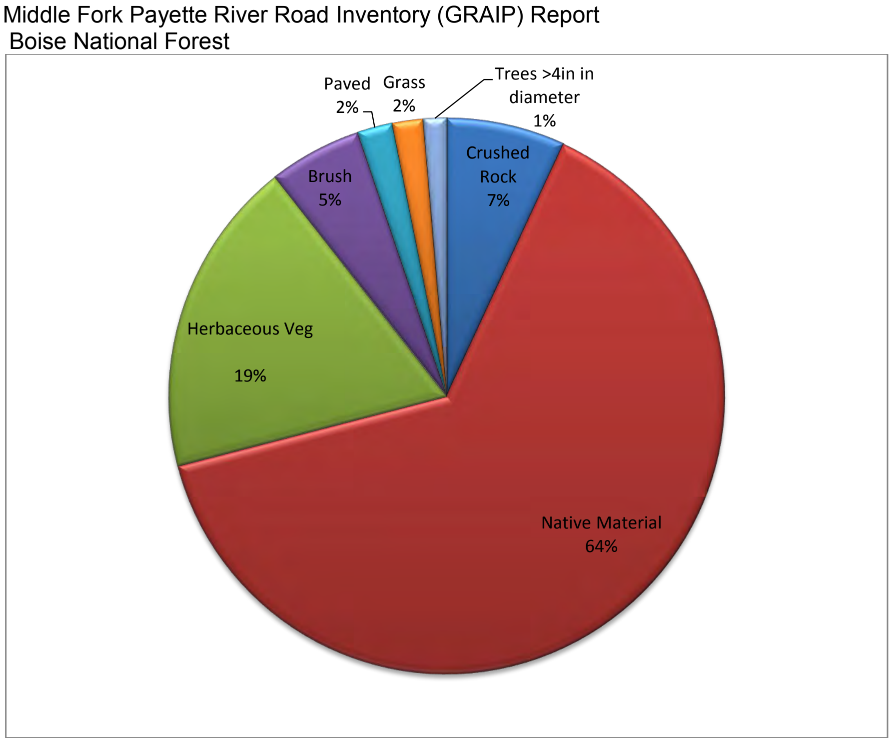


Figure 10. Distribution of road surface types found in the Middle Fork Payette by road length.

Photos 4. The two photos above represent two different road surface types found within the Scriver Creek sub-watershed. *Left:* Herbaceous vegetation surface on FR 695E1. *Right:* Thin layer of crushed rock surface remaining on FR 693.

Vegetation in the flow path, whether a road side ditch, the road surface, or both, is taken into account by the GRAIP model. When the flow path vegetation is observed by the field crew to be greater than 25%, the sediment production rate (amount of sediment eroded off of the road's surface) decreases by a factor of 7. In the Middle Fork Payette Sub basin, 49% of the total flow path length (equivalent to road length) was recorded to have greater than 25% vegetation cover. Relative to other studies and GRAIP road inventories, this figure is rather high. For example, roads inventoried in Bear Valley in 2009 were observed to have greater than 25% vegetation cover in only 27% of total flow path length (Fly et al., 2010). Frequent flow path vegetation can likely be attributed to a high concentration of Maintenance Level 1 roads. Many of these roads have not been graded or otherwise maintained for years, allowing grass, brush, and trees to grow in ditches and on road surfaces. This vegetation has, in many cases, stabilized erosion rates and reduced the impact of chronic sedimentation to streams. However, historic road prisms still pose potential threats to water quality due to risks associated with hillslope and stream crossing failures because old road prisms can intercept and alter surface and subsurface hydrological flow paths and initiate mass wasting events.

2.3 Upstream Sediment Accumulation

Highlighted GRAIP Predictions:

- Total annual accumulated road sediment load is predicted to be 790 tons/yr. and accumulated road sediment rate (road sediment reaching stream per unit area) is estimated at 2.3 tons/mi^2/yr.

GRAIP generates a stream network that is segmented at each channel confluence and each road/stream intersection. For each stream segment, the model calculates the accumulated road sediment load at the downstream end of that segment, including the total accumulated sediment from upstream stream segments (Figure 9). The total predicted amount of accumulated road sediment found in the stream segment nearest to the mouth of The Middle Fork Payette was 790 tons/year. Six Mile Creek has the highest per unit area sediment delivery from roads of 6.4 tons per square mile. Scriver and Anderson Creek have the next highest delivery per area (Table 5).

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Table 5. Stream sediment load values.

Sub-watershed (HUC6)	Total Area (mi^2)	Total Accumulated Road Sediment in Stream (tons/yr.)	Accumulated Road Sediment Rate (tons/mi^2/yr.)	Total Accumulated Natural Sediment in Stream[1] (tons/yr.)	Accumulated Reference Sediment Erosion Rate[2] (tons/mi2/yr.)	Increase over the natural reference sediment	GRAIP-Inventoried Road Density (Rd mi/mi^2) [3]
Scriver Creek	29.9	133.2	4.5	1541	52	9%	4.2
Pyle	30.5	71.3	2.3	1554	51	5%	2.3
Anderson	35.1	159.0	4.5	2203	63	7%	2.5
Lightning Creek	25.8	10.9	0.4	1481	57	1%	0.5
Bull Dog	15.9	0	0.0	933	59	0%	0.2
Rattle Snake	10.6	28.1	2.7	542	51	5%	0.6
Six Mile	40.2	256.7	6.4	2743	68	9%	4.0
Silver Creek	40	60.8	1.5	2243	56	3%	0.7
Bridge-Bryon	26.5	64.4	2.4	1827	69	4%	1.1
Bull Creek	37.9	1.8	0.0	1475	39	0%	0.1
Upper MFP	24.8	3.5	0.1	1442	58	0%	1.2

1. BOISED reference rates from Reinig and others 1991
2. BOISED reference rates from Reinig and others 1991
3. Road density of inventoried roads, some private roads not accessed.

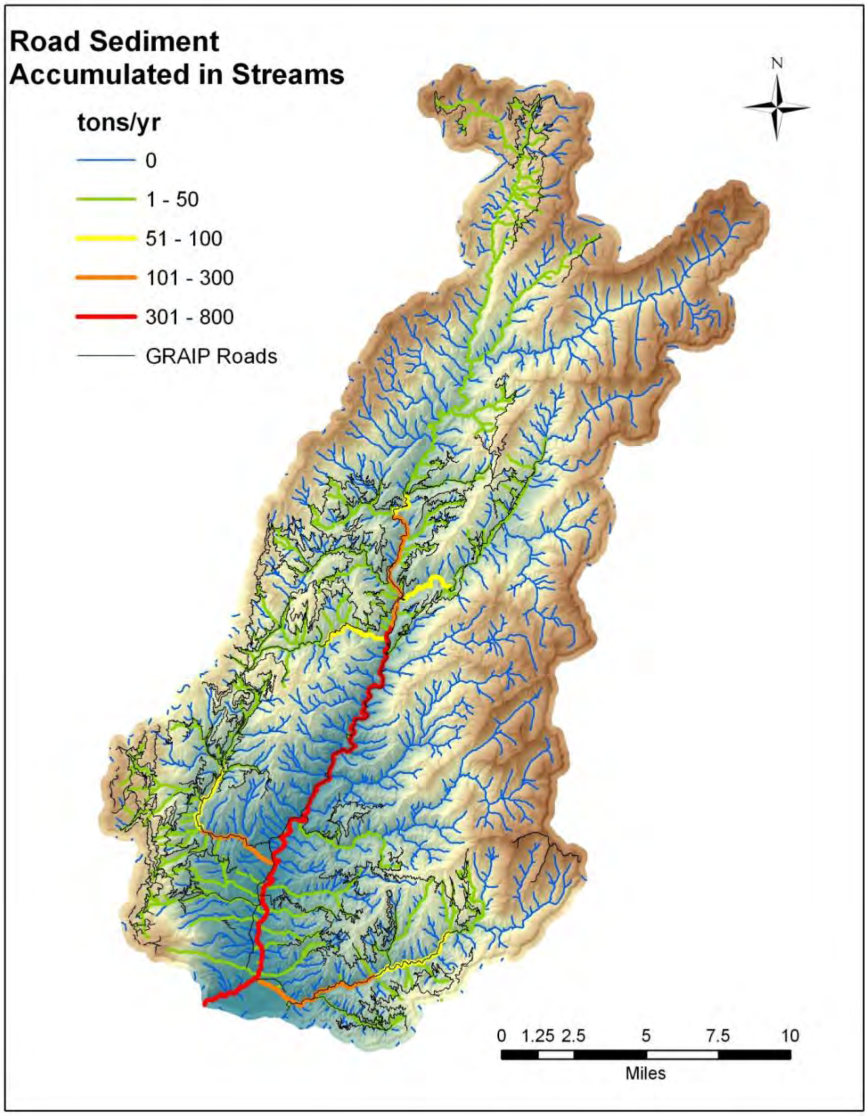

Figure 11. Middle Fork Payette River area map of sub-watersheds and their percentage sediment delivered to stream relative to the rest of the watershed, and stream sediment accumulation from roads.

2.4 Drain Point Condition

Highlighted GRAIP Predictions:

- 10% (1653 total) of drain points were recorded to have condition problems that may require maintenance
- 5% (854 total) of drain points were recorded to have had at least 5 ft^3 of fill material eroded away at the outlet

The GRAIP inventory involves an assessment of the condition of each drain point and a determination of how well it is performing its intended function. Problems with drain point condition are pre-defined for each drain type. Broad based dips are considered to be in poor condition if they are insufficiently outsloped and pond water on the road. Culverts are defined to be in poor condition if they have more than 20% occlusion of the inlet by sediment, substantial inlet crushing, significant rust, or flow around the pipe. Lead off ditches are considered problematic if they have excess deposition or are gullied. Non-engineered features are almost always a problem because they were not designed nor intended to exist. For this exercise, they are considered a problem when caused by a blocked ditch, a gully, a broken outside berm, or a diverted wheel track. They were not evaluated to be problematic when they occurred where a road was outsloped. Stream crossings are considered a problem if they are blocked by sediment or wood, crushed or rusted significantly, incising, scouring or loosing much water from flow around the pipe. Sumps are a problem if they exist unintentionally and pond water on the road surface or cause fill saturation. Water bars that are damaged, under sized, or do not drain properly are defined as problematic. Diffuse drains (outsloped roads) are rarely observed to have drain point problems.

Table 6. Drain point condition problems and fill erosion below drain points.

	Total	Condition problems		Fill Erosion	
Drain Type	Count	Count	Percentage	Count	Percentage
Broad Based Dip	2,147	164	8%	140	7%
Diffuse Drain	4,551	0	0%	17	0.3%
Ditch Relief	2,486	497	20%	96	4%
Lead Off	137	7	5%	0	0%
Non-Engineered	1,810	119	7%	257	14%
Stream Crossing	657	72	11%	53	8%
Sump	133	86	65%	0	0%
Water bar	5,282	708	13%	291	6%
Total	17,203	1653	10%	854	5%

Photos 5. The photos above demonstrate condition problems associated with road drainage infrastructure that exist within the Middle Fork Sub basin. *Top left:* Scott Bergendorf taking measurements at a stream crossing in the Bull Creek Sub watershed that has diverted over the top of the culvert. *Top right:* Fill erosion at a non-engineered drain point on FR 695. *Bottom left:* Fill erosion and infrastructure failure of a log culvert stream crossing on FR 696A. *Bottom right:* Puddles on road and fill saturation at a broad-based dip on FR 693C.

2.5 Stream Crossing Failure Risk

Highlighted GRAIP Predictions:

- 657 stream crossings at roads recorded, 532 constructed with culverts
- Low average Stream Blocking Index (SBI) of 1.6
- Approximately 49,131 yd^3 of fill material are at risk of washing downstream in the event of plugged, overtopped pipes
- 32% (208 out of 657) of stream crossings on roads have the potential to divert stream flow down the road in a major storm event or if plugged

In addition to contributing fine sediment to streams through surface erosion, stream crossings may fail catastrophically when blocked and deliver large sediment pulses to stream channels. Stream crossing failure risks were assessed using the Stream

Blocking Index (SBI, Flanagan et al. 1998). The SBI characterizes the risk of plugging by woody debris by calculating the ratio of the culvert diameter to the upstream channel width and the skew angle between the channel and the pipe inlet.

Field crews recorded a total of 657 stream crossings within the Middle Fork Sub basin. Of these stream crossings, 131 (20%) did not have a round culvert pipe present and were not included in the SBI calculations. These crossings were designed with a bridge, oval pipe, or were decommissioned and excavated, or otherwise did not include a pipe in the design. Risk of pipe plugging does not exist at most of these stream crossing types.

The SBI values for stream crossings within the Middle Fork Sub basin were relatively low with an average value of 1.0 for the 526 assessed stream crossings (Figure 12). The SBI has a range of 1 to 4, where 1 suggests minimal to no risk of blockage. The average pipe to channel width ratio is 1.0 and the median skew angle is less than 25 degrees.

The 480 locations with an SBI less than or equal to 2 typically have pipe to channel width ratios and skew angle combinations that present lower risk. However there are five locations with an SBI of 2 that have a skew angle greater than 75 degrees. The 42 stream crossings with a value of 3 either have moderately undersized pipes with pipe to channel width ratios equal to or less than 0.42, or they have a very high skew angle between the pipe and channel alignment. The four stream crossings with an SBI of 4 have a skew angle of 45 to 75 degrees and are also undersized. One of the crossings with an SBI of 4 has evidence of plugging and diversion in one direction.

Ongoing GIS analysis using the SBI, diversion potential, fill volume and values at risk data will help refine future decisions about where further remediation is required.

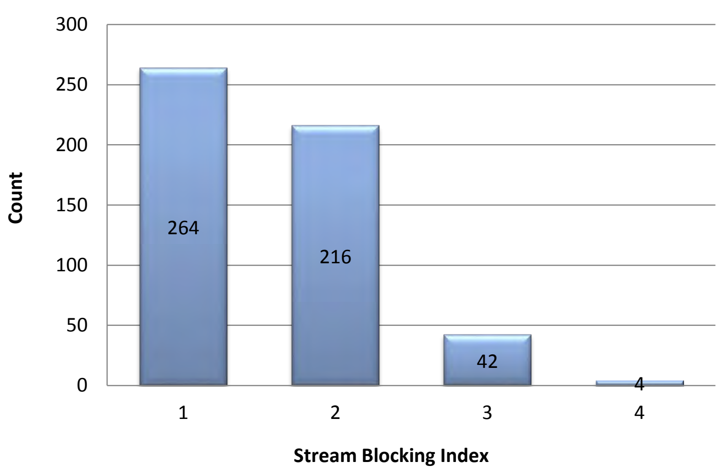

Figure 12. Distribution of Stream Blocking Index (SBI) values. 21 (3%) stream crossing pipes were partially occluded by organic material and sediment and 5 (.7%) were completely occluded by sediment.

The risk of a stream crossing failure can also be viewed in the context of the consequences of failure (Flanagan et al. 1998). A consequence of concern at these stream crossings is the erosion of fill material into the stream channel. The fill material that would likely be excavated in an overtopping type failure was calculated. The prism of fill at risk was modeled as bounded at the base by an area 1.2 times the channel width, with side slopes climbing to the road surface at an angle of 33%. The fill volume at the 527 stream crossings with pipes was approximately 49,131 yd^3.

Photo 6. The three photos above depict a failed stream crossing that where Scriver Creek crosses FR 694 near the headwaters. This crossing showed evidence of being plugged and causing water to flow over the road. This past event (or possible recurring event) eroded away a large amount of fill material, washing it down the channel. The 15 inch diameter pipe is undersized for the estimated 4 foot wide channel at high flow. GRAIP predicted the SBI at this stream crossing to be 3.

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Stream Crossing Type	Count	Average Volume (cu yds)	Total Volume (cu yds)
Steel culvert	401	94	37727
Aluminum culvert	126	91	11405
Steel arch	2	104	208
Log culvert	4	85	340
Total	**533**	**93**	**49679**

A second, and perhaps greater, consequence of concern at failed stream crossings is the diversion of stream flow onto road surfaces and unchannelled hillslopes. Once a crossing becomes occluded and begins to act as a dam, failure can occur in several ways. If the road grade dips into and rises out of the crossing, the failure is likely to be limited to a localized overtopping of the stream crossing. However, if the road grades away from the stream crossing in one or more directions, the flow may be diverted down the road and ditch and onto adjacent hillslopes, where it can cause gullying and/or landsliding (Furniss et al. 1998, Best et al. 1995). This was observed within the Scriver Creek sub watershed during the spring of 2012. A rerouted stream crossing diverted down the 695 road causing slope failure below the road and initiated a debris flow in Hidden Creek that traveled several miles down Scriver Creek depositing a substantial amount of material.

GRAIP addresses this type of issue by classifying the potential for stream crossings to divert stream flow down the adjacent road as one of three options: 1) no potential, 2) potential to divert in one direction, or 3) potential to divert in two directions. In the Middle Fork sub basin, 32% (208 out of 657) of stream crossings on roads had the potential to divert stream flow down the road in one or both directions. The highest risk is from traditional piped stream crossings. 3 stream crossings were observed to have diversion potential in two directions, although one is an excavated stream crossing that is likely to have a low overall risk. Fords and bridges have a low risk and the two pipe arch structures were not at risk of diversion. Taking into account SBI, diversion potential, and fill material volume at risk, stream crossing failure risk in the Middle Fork sub basin is low to moderate.

Table 8. Diversion potential by stream crossing category.

Stream Crossing Type		Diversion Directions			% at Risk
	Count	None	1	2	
Steel culvert round	401	255	144	2	36%
Aluminum culvert	126	80	46	0	37%
Steel arch bottomless	2	2	0	0	0%
Log culvert	4	4	0	0	0%
Natural ford	71	61	10	0	14%
Bridge	26	22	4	0	15%
Excavated	26	24	1	1	8%
Total	657	449	205	3	32%

2.6 Gully Initiation Risk

Highlighted GRAIP Predictions:

- 199 observed gullies.
- 1.5% of all drain points drain to gully. Stream crossings and diffuse drain points are excluded.

Gullying of fill and hillslope material below drain points can be a substantial source of sediment to stream channels. A gully was defined as a linear erosional feature at least ten feet long and six inches deep. 199 gullies were mapped below drain points, not including road and ditch segments that had gullied segments. 187 of the gullied locations were clearly related to road runoff and had mobilized 13,575 cubic yards of material. 13 of these were observed to have stabilized and were no longer actively eroding. 12 gullies were observed to have been caused by hillslope water and mobilized 4,767 cubic yards of material. No estimate of the amount of gully material delivered to the channel was made.

Table 9. Attributes of gullies in the Middle Fork Payette Sub basin including whether they receive road drainage, are actively eroding, their volume and mass.

Road Related	Recent Activity	Count	yds^3	Mass, tons
Yes		**187**	**13,575**	**18,191**
	NOT ACTIVE	13	616	825
	STILL ERODING	174	12,960	17,366
No		**12**	**4,767**	**6,388**
	NOT ACTIVE	4	3,607	4,834
	STILL ERODING	8	1,160	1,554
Totals		**199**	**18,342**	**24,579**

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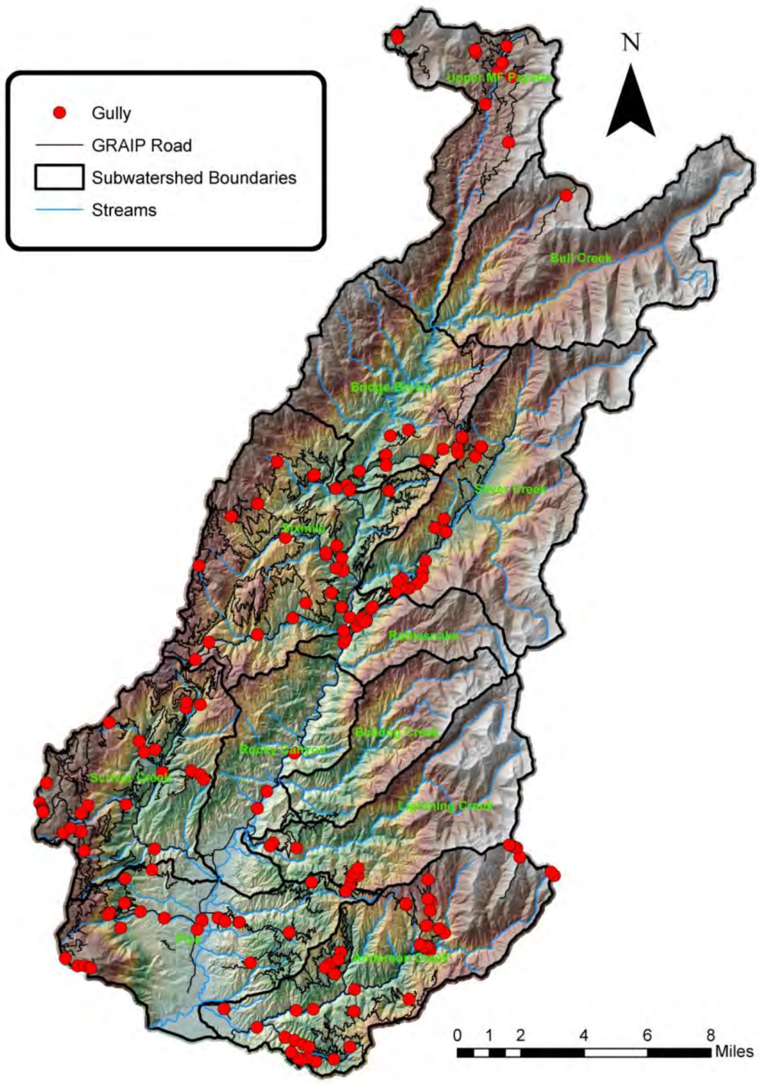

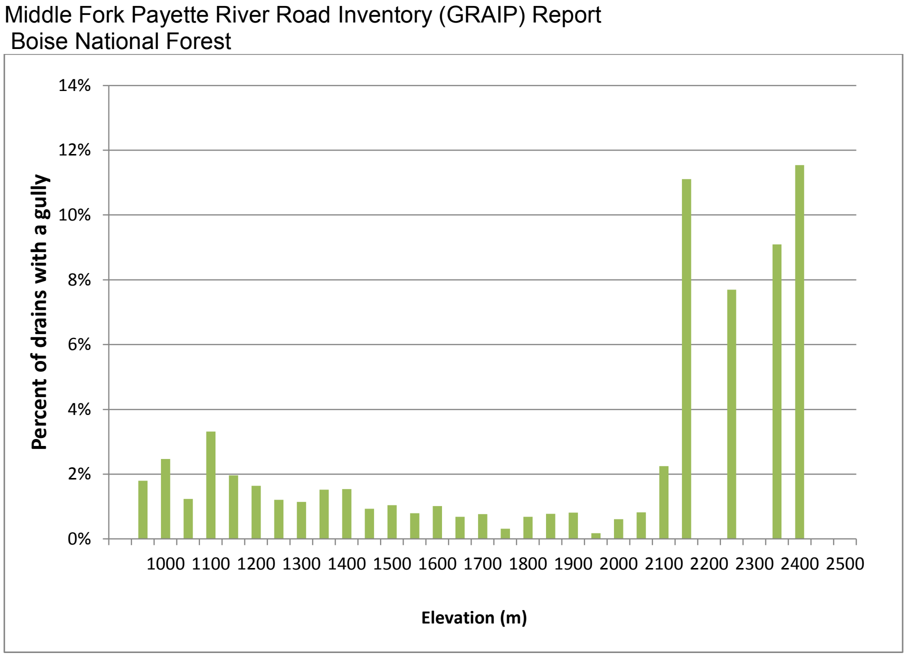

Figure 14. Frequency of gullies in the Middle Fork Payette River sub basin by elevation

Photo 7 (Left) Gully west fork Scriver Creek on 696, this gully is estimated to have 45 cubic feet of erosion and is still actively eroding. *Right:* Two merging gullies on ridge top road 689L5. The feature on the lower left is one of a number of gullies located on the 671 road above Trail Creek.

Gully initiation occurs when the shear stress applied by runoff exceeds the strength of the soil surface on the hillslope. GRAIP computes the Erosion Sensitivity Index (ESI) (Istanbulluoglu et al. 2003), as shown below, at each drainage point.

$ESI = L \times S^2$, where:
L is the road length contributing to the drain point
S is the slope of the hillslope below the drain point.

The average ESI for all drain points was 5.5, with an average contributing road length of 49 m. The average slope of the hillslope below the drain point was 30%. Broad based dips have the highest average ESI and waterbars have the lowest due to differences in contributing road length.

Table 10. The average length and hillslope angle below each drain point type along with the ESI values.

Drain Type	Count	Length (m)	Hillslope (%)	ESI
Broad Based Dip	2,147	72	0.31	8.6
Ditch Relief	2,486	72	0.26	6.6
Lead Off Ditch	137	66	0.19	5.2
Non-Engineered	1,810	53	0.29	6.2
Sump	133	74	0.26	7.0
Waterbar	5,282	27	0.33	3.4
Total	**11,995**	**49**	**0.30**	**5.5**

In many cases ESI values can be compared to a critical ESI threshold (ESIcrit) to identify areas with a high risk of gully formation (i.e., where drain point ESI > ESIcrit). ESIcrit is empirically-derived using inventoried gullies and their probability of occurrence (figure 15). It appears that there is not a sharp ESI threshold in this area but rather a gradual increase above a value of 30 as road length and hillslope increase. The average probability of gully occurrence was observed to be about 1%, while the probability of a gully occurring rose to 6% when ESI exceeded a value of 30.

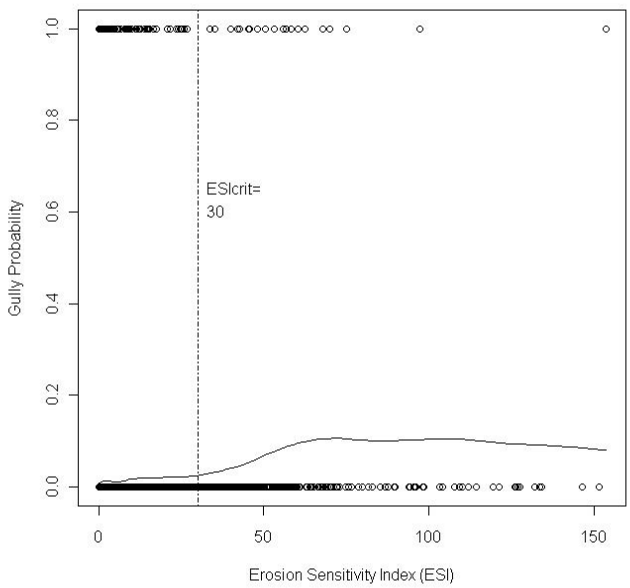

Figure 15. The probability of a gully occurring below a drainpoint as a function of the Erosion Sensitivity Index (ESI). The average ESI was 1%, while the value above the ESI value of 30 was 6%.

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2.7 Landslide Risk

Highlighted GRAIP Predictions:

- 119 total landslides (76 of 119 are road related).

Photo 8. Large landslide of fill slope on a spur road off of 669.

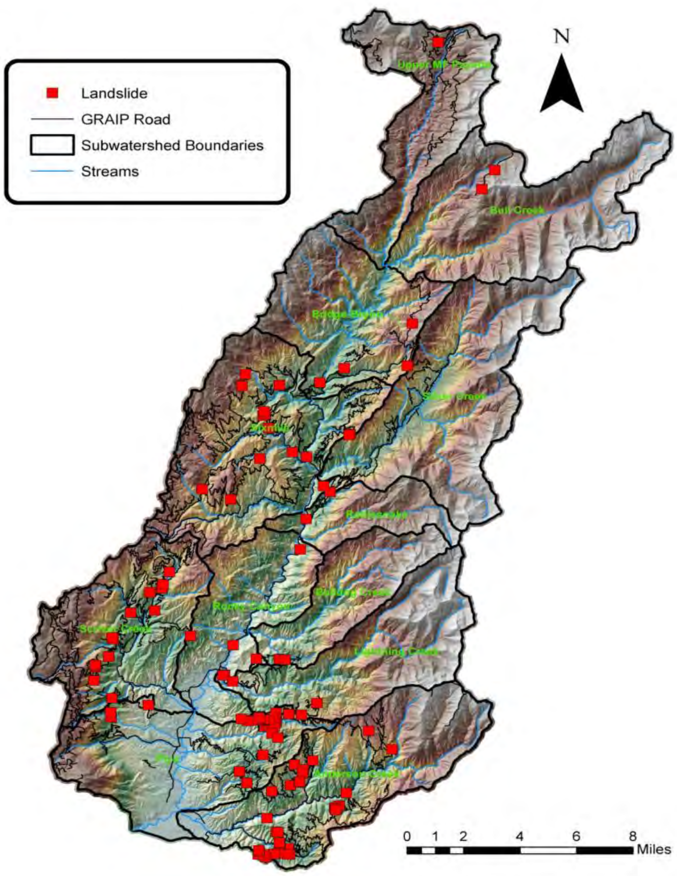


Figure 16. Map of landslides in the Middle Fork Payette sub watershed.

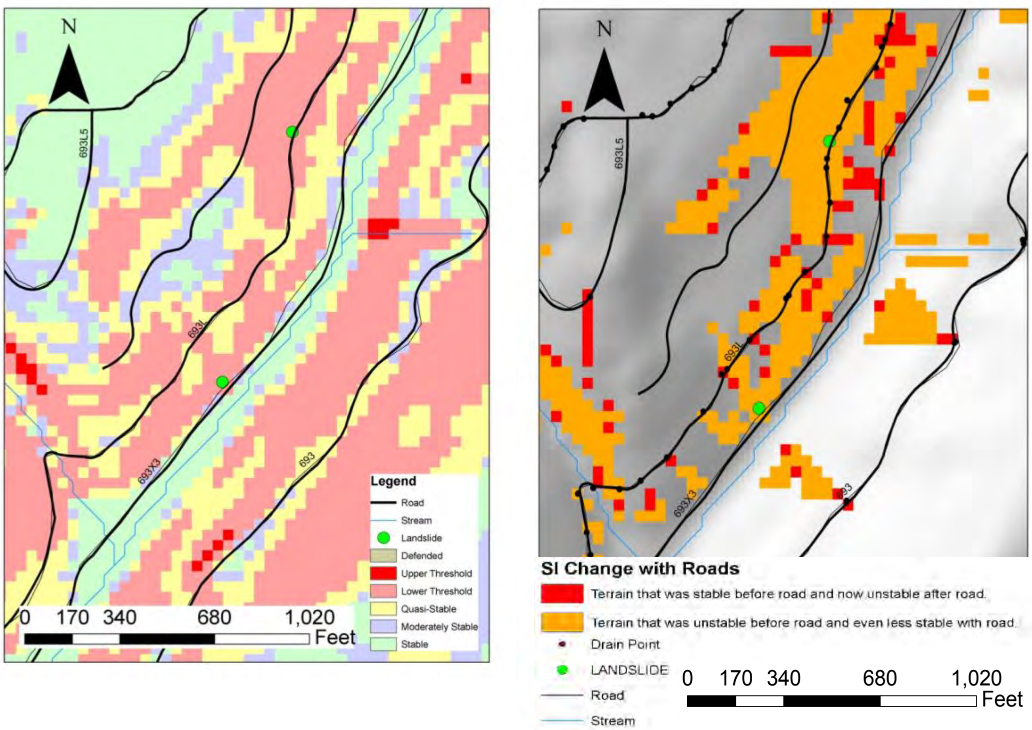
Landslides were mapped in the field using a measuring tape to determine volume. The attributes of the landslide were inventoried including approximate age, relation to road, and location relative to the road. Of the 119 landslides collected 76 were road related. Of the 166,687 yd^3 that were observed at the 119 locations, 117,373 yd^3 (70%) was associated with road drainage Table 11. This means the road contributed to the landslide by interfering with the natural stability of the hillslope. This was identified by observing the failure of the cutslope or fillslope directly above or below the road. The majority of the observed road related landslides and the volume occurred on the fillslope of the roads although size of the average hillslope landslide was nearly three time the volume. Vegetation cover was used to estimate landslide age suggesting that 20% of landslides were less than 5 years old, 55% were less than 10 years old and 25% were less than 15 years old

Table 11. Attributes of landslides including their location, whether they receive road drainage and, their volume and mass.

Location	Road related	Count	Average Volume cu yd.	Total Volume cu yd.	Mass (tons)
CUTSLOPE		23	667	15,334	20,548
	NO	5	1,646	8,229	11,027
	YES	18	395	7,105	9,521
FILLSLOPE		53	1,481	78,503	105,196
	NO	7	1,414	9,901	13,268
	YES	46	1,491	68,602	91,929
HILLSLOPE		38	1,868	71,002	95,145
	NO	28	1,098	30,740	41,193
	YES	10	4,026	40,262	53,952
SLUMP		5	370	1,848	2,476
	NO	3	115	344	461
	YES	2	752	1,504	2,015
Total		119	1,401	166,687	223,365

The risk of shallow landslide initiation is predicted using SINMAP 2.0 (Pack et al., 2005, http://hydrology.neng.usu.edu/sinmap2/), then modified to account for contributions of road runoff. An example from NFSR 693L is shown in Figure 17 to illustrate the change in risk in an area where the inherent landslide risk is high. This risk is assessed by referring to an index referred to as the Stability Index (SI). SINMAP was run initially to determine the intrinsic stability (SI) of the slopes over which the road traverses and to identify locations that are at high risk of failure without a road (Figure 17a).

Figure 17. Stability index for hillslopes in the vicinity of Road NFSR 693L.
a) (left) SI value for hillslopes in a un-roaded condition. **b)** (right) Negative changes in SI due to the addition of road drainage.



A second stability index run was performed to address the effects of road water contribution to drain points on the road network. This second stability index run is referred to as the Stability Index Combined (SIC) because it accounts for both the naturally inherent risk of hillslope failure in a landscape and the added risk from roads. Slope stability analysis is only available for the Scriver Creek sub watershed at the time of writing as the detailed SinMap analysis for the MF Payette sub basin is incomplete.

3.0 Summary and Conclusion

The BNF and the RMRS initiated a road inventory project to include all roads in the Middle Fork Payette River sub basin from 2009-2011. Funding was provided through the EPA. Field crews inventoried road segments throughout the Middle Fork Payette drainage while a data manager and a GIS technician processed and analyzed the data that was collected in the field. The GRAIP model was used to predict the level of impact/risk that existing roads posed on streams.
Inventory data was collected on over 520 miles of road, including 17,203 drain points, by field crews during three field seasons. An investment made in crew training and oversight paid off in the form of well documented precision and accuracy measures. Study objectives were identified as outlined in Section 2.0 of this report. These objectives were met and the questions posed were answered as shown below.

1. What is the existing level of fine sediment delivery from roads to streams in the Middle Fork Payette Watershed?
a. How does the contributed sediment from roads compare to natural reference sediment levels?

The length of the sampled road that was hydrologically connected to streams totaled 113 mi out of the 583 mi of inventoried road (19%). The model predicted that the existing level of fine sediment delivery from roads to streams amounts to 790.1 tons annually, which is 20% of the predicted annual fine sediment production total of 3,918.4 tons. Road sediment that accumulates in the stream network annually is predicted by the model to be 790.1 tons. The accumulated road sediment per unit area for the entire Middle Fork of the Payette is predicted to be 2.3 tons/mi2/year. Compared to the watershed's natural reference sediment accumulation rate of 52 tons/mi2/yr., added road sediment yields a 4% increase.

There is considerable variability in the modeled sediment delivery between the individual sub basins and how that relates to background. Scriver and Six Mile Creeks are predicted to be 9% above the BOISED background, while Bull Dog, Bull Creek and the Upper Middle Fork Payette were not significantly impacted by road sediment with 1% or less above background.

2. Where are the locations of highest sediment delivery from roads to streams?
a. Can these sites be reconstructed to eliminate or minimize delivery?

As indicated in Figures 5, locations of high sediment delivery within the Middle Fork Payette are relatively localized with some of the highest delivery in valley bottom road locations. This is in part because historically road location was confined to valley bottoms by the topographic and engineering constraints. The sediment delivery is also concentrated in a few locations. 12% of all drain points and 8% of road length delivers all of the sediment to streams. This insight can help management prioritize the largest sediment targets first. The 668 and associated roads in Anderson Creek, the 698 road in Silver Creek and the 696 in the West fork of Scriver Creek have 26 of the top 100 delivering drain points in the study area accounting for 18% of the basin total delivery. Road-stream connection often occurs at or near live stream crossings on roads. Although these predicted locations of high sediment delivery are based on thorough field observations and careful data processing, more thorough field surveys of the indicated road segments and drain points need to be completed in order to design effective management plans. A few such field observations have already proven helpful in calibrating the severity of problematic features and assessing the need for remediation. Reconstruction of such sites is possible and feasible in most cases. In order to decrease sediment delivery, road improvements may involve the addition of more frequent road drainage features, leaving a shorter distance between features. This would decrease the energy of concentrated flow to individual drain points, thus shortening the distance that water and sediment travels down the hillslope. Treatments may also include re-surfacing the road with a crushed rock aggregate or another type of surface which is less erosive. In the case of NFSR 696, plans are being prepared to decommission this road and reroute it farther from the stream.

As a whole, these results indicate that specific roads within the Middle Fork Payette do pose some risk to water quality and associated beneficial uses. It is also evident that a feasible amount of project work could eliminate a substantial portion of this risk.

By making improvements to about 11 miles of road, up to 50% of fine sediment delivery from roads could be addressed. Reconstructing 70 miles of road could address road segments that are responsible for all of the sediment delivery.

The incidence of road related landsliding (76 occurrences) was observed to be lower than expected. Road related gully occurrence was more common but the threshold for gully initiation was relatively high compared to other locations. Future restoration work can reduce the drainage to active gullies and landslides that deliver chronic sediment to channels. The ESI threshold will inform future road design work on steep unstable granitic hillslopes to minimize the risk of gully occurrence.

With the benefit of the GRAIP inventory data future work could also be effective in greatly reducing many of the hydrogeomorphic impacts and risks that these roads pose to water quality and associated beneficial uses. This analysis will allow forest managers to efficiently prioritize resource restoration plans based on site-specific data.

4.0 References

Best, D.W., Kelsey, H.M., Hagans, D.K., and M. Alpert. 1995. Role of fluvial hillslope erosion and road construction in the sediment budget of Garret Creek, Humboldt County, California in Geomorphic Process and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. Nolan, K.M., Kelsey, H.M., and D.C. Marron, editors. USGS professional paper #1454. pp. m1-m9.

Black, T. A., Cissel, R. and Luce, C. H. 2012. The Geomorphic Road Analysis and Inventory Package (GRAIP) Volume 1: Data Collection Method. Gen. Tech. Rep. RMRS-GTR-280WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Black, T. A. and Luce, C. H. 2013. Measuring Water and Sediment Discharge from a Road Plot with a Settling Basin and Tipping Bucket. Gen. Tech. Rep. RMRS-GTR-287.

Middle Fork Payette River Road Inventory (GRAIP) Report
Boise National Forest
Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Black, T.A., Luce, C.H., Monschein, E., and L. Woodruff. 2009. Geomorphic Road Analysis and Inventory Package (GRAIP) Field Collection Activities: Quality Assurance Project Plan (QAPP). USDA Forest Service Rocky Mountain Research Station and U.S. Environmental Protection Agency Region 10 and Headquarters 303 (d) Program Offices.

Cissel, R. M., Black, T. A., Schreuders, K. A. T., Prasad, A., Luce, C. H., Nelson, N.A., Tarboton, D.G., and Nelson, N. A. 2012A. The Geomorphic Road Analysis and Inventory Package (GRAIP) Volume 2: Office Procedures. Gen. Tech. Rep. RMRS-GTR-281WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Flanagan, S.A., Furniss, M.J., Theisen, S., Love, M., Moore, K., and J. Ory. 1998. Methods for Inventory and Environmental Risk Assessment of Road Drainage Crossings. USDA Forest Service Technology and Development Program 9877-1809-SDTDC. 45 pp.

Fly, C. K. Grover Wier, J. Thornton, and T. Black. 2011. Bear Valley Road Inventory (GRAIP) Report. Bear Valley Category 4b Assessment. Lowman Ranger District, Boise National Forest. Lowman, ID. 44p.

Furniss, M.J., Love, M., and S.A. Flanagan. 1997. Diversion Potential at Road Stream Crossings. USDA Forest Service Technology and Development Program 9777-1814-SDTDC. 12 pp.

Istanbulluoglu, E., Tarboton, D.G., Pack, R.T., and C.H. Luce. 2003. A sediment transport model for incision of gullies on steep topography. Water Resources Research. 39(4): 1103-1117.

Jones, J.A. and G.E. Grant. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon, Water Resources Research, 32, 959-974.

Luce, C.H. and T.A. Black. 1999. Sediment production from forest roads in western Oregon. Water Resources Research. 35(8): 2561-2570.

Madej, Mary A. 2001. Erosion and Sediment Delivery Following Removal of Forest Roads, Earth Surface Landforms and Processes, 26(2) pp.175-190.

Pack, R. T., Tarboton, D.G., Goodwin, C.N., and A. Prasad. 2005. SINMAP 2.0 A Stability Index Approach to Terrain Stability Hazard Mapping, technical description and user's guide for version 2.0, Utah State University.

Prasad, A. 2007. A tool to analyze environmental impacts of road on forest watersheds. MS Thesis. Utah State University, U.S.A.

Prasad, A., Tarboton, D.G., Schreuders, K.A., Luce, C.H., and T.A. Black. 2007. GRAIP1.0 Geomorphic Road Analysis and Inventory Package: A tool to analyze the environmental impact of roads on forested watersheds. Tutorial and Reference Manual. http://www.engineering.usu.edu/dtarb/graip.

Shapiro, D. and associates. 2000. Bear Valley Watershed Analysis. USDA Forest Service, Boise National Forest, Lowman Ranger District. 262 pp.

Reinig, L., Beveridge, R.L., Potyondy, J.P., and F.M. Hernandez. 1991. BOISED User's Guide and Program Documentation. USDA Forest Service, Boise National Forest. V. 3.01.

Middle Fork Payette River Road Inventory (GRAIP) Report
Boise National Forest
Wemple, B.C., Jones, J.A., and Grant, G.E. 1996. Channel network extension by logging roads in two basins, western Cascades, Oregon, Water Resources Bulletin, 32, 1195-1207.

Appendix A: Glossary of Selected Terms

Below is a list of terms, mostly of drainage point types, but also of some other commonly used terms, for the purpose of clarification. Adapted from Black, et al. (2011), Fly, et al (2010), and Moll (1997).

Broad based dip. *Constructed:* Grade reversal designed into the road for the purpose of draining water from the road surface or ditch (also called dip, sag, rolling grade, rolling dip, roll and go, drainage dip, grade dip). ***Natural:*** A broad based dip point is collected at the low point where two hillslopes meet, generally in a natural swale or valley. This is a natural low point in the road that would cause water on the surface of the road to drain out of the road prism.
Cross drain. This is not a feature collected specifically in GRAIP, and it can refer to a number of other drainage features. It is characterized by any structure that is designed to capture and remove water from the road surface or ditch. Ditch relief culverts, waterbars, and broad based dips can all be called cross drains.
Diffuse drain. This is a point that is characterized by a road segment that does not exhibit concentrated flow off the road. Outsloped roads or crowned roads often drain half or all of the surface water diffusely off the fillslope. Although collected as a drain point, this feature is representative of an area or a road segment rather than a concentrated point where water is discharged from the road prism. A drop of water that lands on a diffuse road segment will not flow down the road or into the ditch, but more or less perpendicular to the centerline off the road surface and out of the road prism. Also called sheet drainage or inter-rill flow.
Ditch relief culvert. This drain point is characterized by a conduit under the road surface, generally made of metal, cement, or wood, for the purpose of removing ditch water from the road prism. This feature drains water from the ditch or inboard side of the road, and not from a continuous stream channel.
Flow path. This is the course flowing water takes, or would take if present, within the road prism. It is where water is being concentrated and flowing along the road from the place where it enters the road prism, to where it leaves the road prism. This can be either on the road surface, or in the ditch.
Lead off ditch. This drain point is characterized by a ditch that moves flow from the roadside ditch and leads it onto the hillslope. Occurs most often on sharp curves where the cutslope switches from one side of the road to the other. Also known as a daylight ditch, mitre drain, or a ditch out (though this term can also describe other types of drainage features).
Non-engineered drainage. This drain point describes any drainage feature where water leaves the road surface in an unplanned manner. This can occur where a ditch is dammed by debris, and the water from the ditch flows across the road, where a gully crosses the road, where a wheel rut flow path is diverted off the road due to a slight change in road grade, or where a berm is broken and water flows through. This is different from a diffuse drain point, which describes a long section of road that sheds

water without the water concentrating, whereas this point describes a single point where a concentrated flow path leaves the road.

Orphan drain point. This is any drain point that does not drain any water from the road at the time of data collection. Examples include a buried ditch relief culvert, or a water bar that has been installed on a road that drains diffusely.

Stream crossing. This drain point is characterized by a stream channel that intersects the road. This feature may drain water from the ditch or road surface, but its primary purpose is to route stream water under or over the road via a culvert, bridge, or ford. A stream for the purposes of GRAIP has an armored channel at least one foot wide with defined bed and banks that is continuous above and below the road and shows evidence of flow for at least some part of most years.

Sump. ***Intentional:*** A closed depression where water is intentionally sent to infiltrate. ***Unintentional:*** Any place where road water enters and infiltrates, such as a cattle guard with no outlet, or a low point on a flat road.

Waterbar. This drain point is characterized by any linear feature that is perpendicular to the road that drains water from the road surface and/or ditch out of the road prism or into the ditch. Waterbars may be constructed by dipping the grader blade for a short segment, or adding a partly buried log or rubber belt across the road. Some road closure features may also act as a waterbar, such as a tank trap (also known as a closure berm or Kelly hump). Cattle guards that have an outlet that allows water to flow out are also considered to be water bars. These features may also be known as scratch ditches if they drain water into the ditch.

Appendix B: Sediment Plot Results

To obtain local calibration for the GRAIP model, erosion plots were installed using the method outlined in Black and Luce 2013. These plots were 80 meters in road length, between 5 to 6% slope and are located on native surface forest roads that receive low to moderate levels of light vehicle traffic. The roads are built on granitic parent material. Plots were installed in September of 2009 and data collection is ongoing. There are three and a half years of data available as of this writing.

Commented [UFS1]: Add citation

Photo 9. Typical road plot on left and sediment tank on the right.

Weather observations were obtained from at a weather station located at the US Forest Service Garden Valley Work Center located approximately 9 miles from the sediment plot locations along the Lightning Creek road (NFS road 611). The average annual precipitation between 1949 and 2012 for the Garden Valley area was 24.4 inches per year with the majority falling as winter snow. Rainfall that arrives during the spring and summer months often is delivered by convective storms. This precipitation has a higher potential to cause erosion and sediment transport as it is delivered over a short period of time, typically less than an hour. The USFS Garden Valley weather station typically receives a total of 5.0 inches of precipitation in the months from May through September. During the period of study beginning in the 2010 water year, this gage received a total of 4.4 (2010), 0.9 (2011), and 0.4 (2012) inches of precipitation during May through September.

Commented [UFS2]: Do we have May-Sept 2013?

The annual and seasonal precipitation varied considerably between the years of the sediment plot study from 2010 through 2013 (Figure 18, 19). A second rain gage is located within 2.5 miles of the study area in the Terrace Lakes subdivison. The 2010 water year delivered 40.4 inches, while 2012 delivered 22.7 inches.

Commented [UFS3]: This part is a bit confusing, are these totals for the gage near Scriver? Or for GV?

I was a bit confused about what you said in your email. I believe the WO GARDEN VALLEY 2SE RANGER STATION ID US USBR gage is the one at the ranger station. The other gage "near Scriver" appears to be a NWS coop site… I see it as station D8224 Garden Valley in Mesowest

We should figure out what to call this… because I don't think this gage is in Scriver Cr… Actually appears to be in the Terrace Lakes Subdivision

Commented [UFS4]: Is that day of the water year? Oct-sept

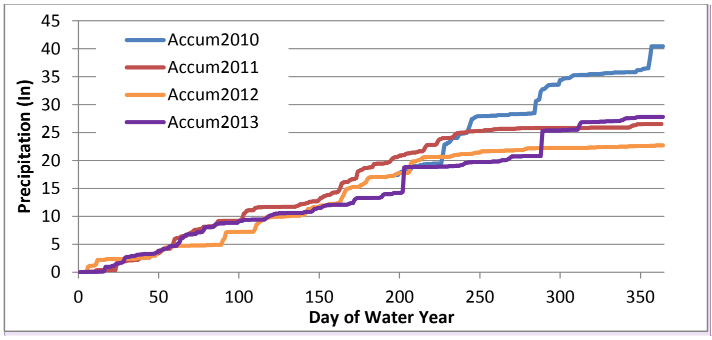


Figure 18. Annual precipitation accumulation by day of the water year for the Terrace Lakes gage during the period of study.

The more significant difference with regard to erosion is the almost complete absence of summer precipitation in the dry years. In the period of May through September 2011 the Terrace Lakes gage received 5 inches and in 2012 only 2.7 inches, compared to 9 inches in 2013 and 21.5 in 2010.

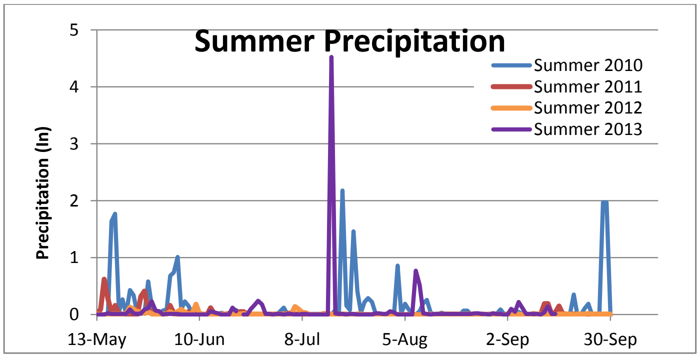


Figure 19. Precipitation received in the spring and summer during the sediment plot study from the Terrace Lakes gage. Note the near absence of summer precipitation in 2011 and 2012.

At the beginning of the study period in 2010, the road was open to traffic and had been used by heavy equipment to conduct an organic matter mastication project. In the winter of 2011 a landslide occurred on the lower portion of the road, effectively excluding most traffic with the exception of ATVs. The road was repaired in 2012. The road did not receive any grading or heavy vehicle traffic during the study.

The average erosion from the group of plots declined over the three years of observation from 226 kg, in 2010 to 43 kg in 2011 to 26 kg in 2012. This declining trend reflects the impact of the initial disturbance of the plot installation, the lack of traffic during the middle portion of the data collection and a lack of intense convective activity at this location during 2011 and 2012.

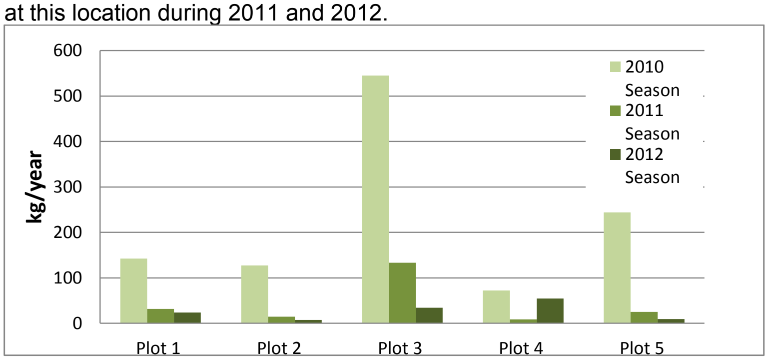


Figure 20. Annual erosion form sediment plots located on Lightning Creek in the Middle Fork of the Payette.

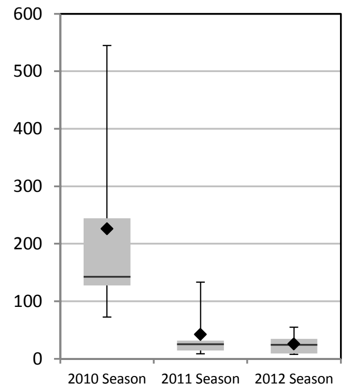


Figure 21. Annual erosion in kilograms at the Lightning Creek plots. Mean value represented by diamonds, the median is represented by the dark line.

Sediment measurements were taken seasonally in October and May during 2012 and 2013 to investigate the seasonal distribution of sediment transport from the road (Figure 22). Previous erosion studies in nearby Silver Creek (Megahan 1983, Megahan and Ketcheson 1996) suggests that snow melt runoff rates are generally too low to result in substantial surface erosion in this area and consequently that summer convective storms and the rare rain on snow event are the most important drivers of sediment production.

While more than 2 years of data are needed to understand the influence of seasonal precipitation patterns on erosion events, this sample suggests that limited erosion occurs in dry summer and that fall and winter runoff should not be discounted as drivers of sediment transport. The largest single sample of erosion occurred at plot 3 during the winter of 2010 and accounted for 48% of the total erosion in the first year and 35% of the total erosion from three years.

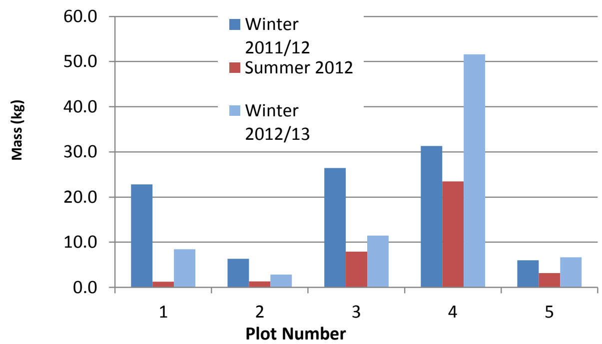


Figure 22. Erosion by season at the Lightning Creek road plots.

Middle Fork Payette River

GRAIP Watershed Assessment

USDA Forest Service, Boise National Forest

September 2013

Scott Bergendorf[1], Brian Anderson[1], Tom Black[2], Megan Jenkins[1], John Thornton[1] and Charles Luce[2]

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Boise National Forest

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Executive Summary

The US EPA began funding a site-specific road sediment inventory in 2009 within the Middle Fork Payette River Sub basin to assist with the implementation plan to meet water quality obligations associated with an assigned Total Maximum Daily Load (TMDL) for sediment (State of Idaho 1998 and 2003). Over 580 miles of roads were mapped and surveyed by field crews from 2009 to 2011. The completed portion of the survey accounts for more than 95% of National Forest System (NFS) roads. In 2011, field crews focused on surveying all accessible state, county, private, or other non-NFS jurisdictional roads. Approximately 90% of state roads and 15% of private roads were collected during this year. Overall, about 70% of the sub basin has been surveyed. This inventory quantified the extent and location of sediment contributions from roads to streams, using the Geomorphic Road Analysis and Inventory Package (GRAIP, Black and others 2012, Cissel and others 2012, Prasad et al. 2007, http://www.fs.fed.us/GRAIP). This robust suite of inventory and analysis tools evaluates the following impacts and risks of roads: road-stream hydrologic connectivity, fine sediment production and delivery, upstream sediment accumulation, drain point condition, stream crossing failure risk, gully initiation risk, and shallow landslide risk.

The Middle Fork Payette River Sub basin is a 339 mi^2 4th field hydrologic unit within the Payette River watershed in central Idaho. The Middle Fork Payette River Sub basin contains four 5th field watersheds and twelve 6th field sub watersheds. The Boise National Forest (BNF) collaborated with the Rocky Mountain Research Station (RMRS) to complete a GRAIP road inventory in the Middle Fork Payette River Sub basin and develop risk profiles for the surveyed roads to assess impacts and risks to key watershed processes. A summary of predicted risks is displayed in Table 1.

Field crews mapped and collected data on a total of 583 miles of roads within the Middle Fork Payette River Sub basin, suggesting a road density of 1.7 mi/mi^2 (actual road density is assumed to be higher as 100% of roads were not surveyed during this inventory). While the majority of NFS and State roads in the sub basin are included in these 583 miles of surveyed road length, it is estimated that there may be up to 100 more miles of county, private, and unmapped Forest roads that remain unsurveyed (increasing road density to approximately 2 mi/mi^2).

In many cases, old roads overgrown with brush and trees were encountered by crews in the field but could not be located on any available map or GIS layer. It was found that,

throughout the sub basin, many areas exist that have undergone past timber management utilizing road based yarding systems and not all road prisms are accounted for. There also exist many geometrical discrepancies among existing road GIS layers and the shapes of roads as physically mapped in the field and visualized on areal mapping.

Road-stream hydrologic connectivity was calculated to be 113 miles (19% of all road length surveyed). The total amount of fine sediment from roads accumulating in the Middle Fork Payette River and its tributaries was 790.1 tons/yr, which accounts for 20% of all sediment produced on surveyed roads. The predicted sediment delivery rate from roads of 2.3 tons/mi^2/yr. suggests a 4% increase above the natural reference sediment erosion rate as predicted by the BOISED model (Reinig et al. 1991).

Approximately 10% of road drainage features were recorded to be in poor condition or in need of maintenance. The risk of stream crossings becoming plugged was evaluated based on a stream blocking index (SBI) where 1 indicates virtually no risk and 4 indicates high risk. The average SBI for stream crossings in this survey was 1.6. A total of 32% of all stream crossings have diversion potential, suggesting a moderate to high risk of stream water flowing down the road prism and hillslope if the pipe is blocked. An estimate of 49,131 yd$^{3\ \text{was}}$ made of fill volume at risk at stream crossings.

Slope stability data, which includes the frequency and attributes of observed landslides and gullies, is used to calculate gully initiation risk and landslide potential resulting from roads. 119 hillslope failures were observed and recorded in the survey. 199 gullies were observed of which 187 were determined to be related to excessive road drainage. Surveys of the gully volume determined that 13,578 yd^3 have been eroded at these location over the time since construction. An Erosion Sensitivity Index (ESI) was calculated for the gullies and determined that the probability of gullying increased from about 1% to 6% when long road segments drained to steep unstable hillslopes.

Quality assurance measures were taken in order to ensure the integrity of the data collected. Field crews were trained on data collection methods by individuals considered experts in using the GRAIP inventory protocol. Quality assurance plots were surveyed by each crew and by an expert crew in order to ascertain relative precision and bias of data collected. Results suggest that the margin of error among data collected by the different crews was acceptable and that the data are considered usable for analysis. Crews were audited monthly during the survey of a road by an expert who corrected procedural mistakes in real time and provided additional training.

Taken collectively, inventory results indicate that several portions of the road network throughout the sub basin result in accelerated sedimentation and risks to aquatic ecosystems. Relative to road sediment production, sediment delivery is moderate to high on several roads (e.g. NFS roads 668 (Anderson Creek), 696 (Middle Fork Scriver Creek), and 698 (Middle Fork Payette River)), while the location (distance from waterways) of other roads makes them essentially benign in regard to sediment delivery. The granitic material in the area weathers to form a poorly cohesive soil and much of the road network does not have a resistant surfacing material. Each individual road has different use and management qualities associated with it and this presents various options to reduce road sediment delivery including road surfacing, drainage feature maintenance, and road decommissioning. GRAIP predictions can be used to address the needs of specific road segments and drain points in the design and implementation phases of future road restoration or road maintenance projects.

Table 1. Summary of GRAIP model risk predictions for the Scriver Creek sub-watershed.

Impact/Risk Type	GRAIP Prediction
Road-Stream Hydrologic Connectivity	113 miles, 19% of total road length
Fine Sediment Production (not delivered to stream)	3918.4 tons/year
Fine Sediment Delivery	790.1 tons/year, 20% of fine road sediment production
Upstream Sediment Accumulation	790.1 tons/year, 20% of fine road sediment production
Upstream Sediment Accumulation Rate	2.3 tons/mi^2/year, 4% over natural reference sediment erosion rate
Drain Point Problems	1653 drain points, 10% of all drain points.
Stream Crossing Failure Risk	
- plug potential	46 stream crossings with elevated risk, 9% of total
- fill at risk	49,131 cubic yards
- diversion potential	208 stream crossings, 32% of total
Gully Initiation Risk	174 of 199 observed gullies are road related and mobilize 18,191 tons occur at 1% of all drainpoints
Landslide Risk	76 of 119 landslides road related, with a volume of over 157,400 tons

Photo 1. Captions to photos on cover. *Top left:* Erosion on road draining to the Middle Fork Payette River above Tie Creek Campground. *Top right:* Jim Bitzenburg and fillslope erosion on road 662A. *Middle right: D*itch relief on a Private Driveway. *Bottom right:* Typical ditch relief in the Middle Fork Watershed with some fill erosion occurring.

Middle Fork Payette River Road Inventory (GRAIP) Report
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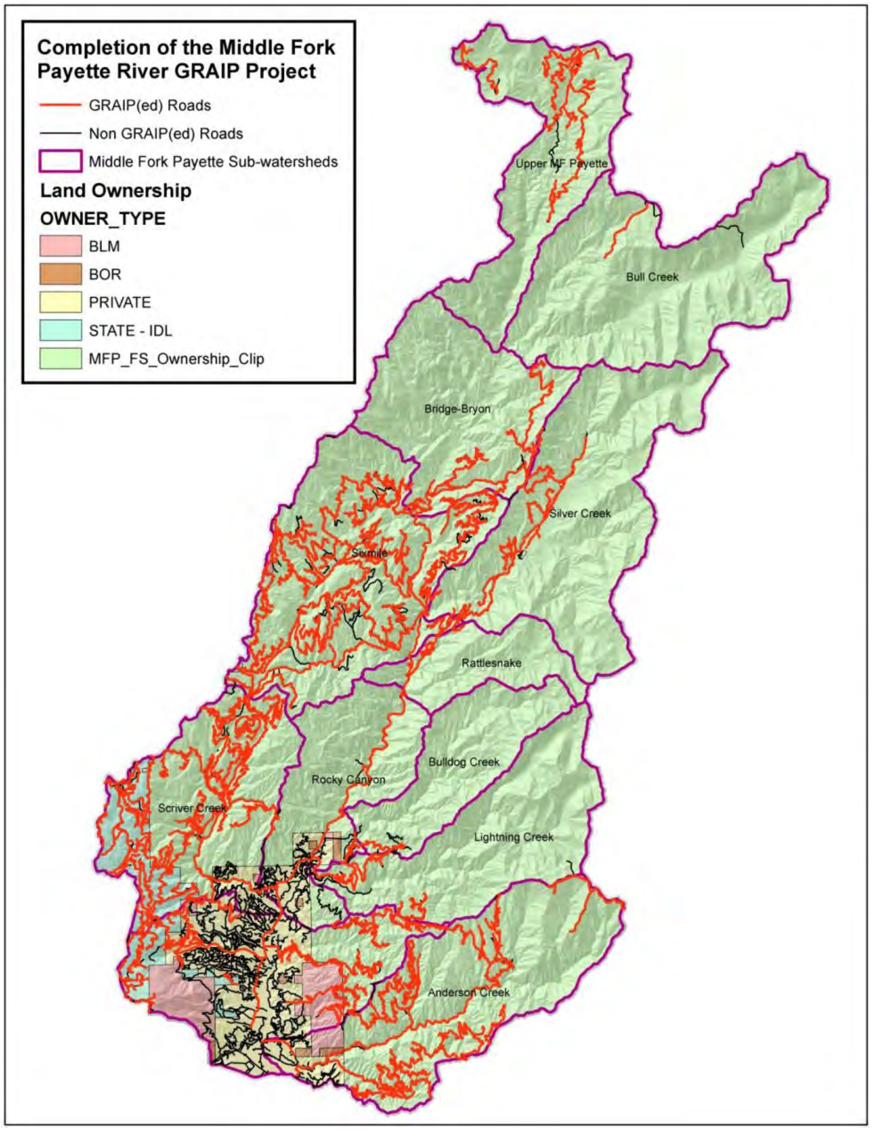
Figure 1. Map of the Middle Fork of the Payette Sub basin. Map Illustrates completed roads using the GRAIP survey method.



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1.0 Methods

The Geomorphic Roads Analysis and Inventory Package (GRAIP) was used to inventory and model the risk profile of each of the road segments included in the study. The GRAIP system consists of a detailed, field-based road inventory protocol combined with a suite of geographic information system (GIS) models. The inventory is used to systematically describe the hydrology and condition of a road system using Geographic Positioning System (GPS) technology and automated data forms (Black and others 2012, Cissel and others 2012, and Luce 1999). The GIS models use these data to analyze road-stream hydrologic connectivity, fine sediment production and delivery, upstream sediment accumulation, stream sediment input, shallow landslide potential with and without road drainage, gully initiation risk, and the potential for and consequences of stream crossing failures. Detailed information about the performance and condition of the road drainage infrastructure is also supplied. The inventory was conducted in accordance with the Quality Assurance Project Plan (QAPP) developed in cooperation with the USEPA and the RMRS (Black et al. 2009).

2.0 Results

GRAIP inventory and modeling tools were used to characterize the following types of impacts and risks:

- Road-stream hydrologic connectivity
- Fine sediment production and delivery
- Upstream sediment accumulation
- Drain point condition
- Stream crossing failure risk
- Gully initiation risk
- Landslide risk

A brief summary of each impact or risk is included in this report with relevant tables, charts, graphics, and photos.

2.1 Road-stream Hydrologic Connectivity

Roads can intercept shallow groundwater and convert it to surface runoff, particularly in steep terrain, resulting in local hydrologic impacts when that water is discharged directly to channels (Wemple et al. 1996). Additional runoff is also produced from the compacted road surface. Basin-scale studies in the Oregon Cascades suggest that a high degree of integration between the road drainage system and the channel network can increase peak flows (Jones and Grant 1996).

GRAIP calculates the hydrologically-connected portion of the road using the field assessment of drain point connection and a road segment flow routing system. The flow path below each drain point is followed until evidence of overland flow ceases or the flow path reaches a channel. A total of 113 mi (182 km) out of the 583 mi (938 km) of surveyed roads in the Middle Fork Payette Watershed (19%) were hydrologically connected to a stream.

2.2 Fine Sediment Production & Delivery

Fine sediment production for a road segment (E) is estimated based on a base erosion rate and the properties of the road (Luce and Black 1999), as shown below. Sediment production is calculated for two unique flow paths on each road segment.

$E = B \times L \times S \times V \times R$

B is the base erosion rate[1] (kg/m/yr.)
L is the road length (m) contributing to the drain point
S is the slope (m/m) of the road segment
V is the vegetation cover factor for the flow path
R is the road surfacing factor

Delivery of eroded sediment to the channel network is determined by observations of each place that water leaves the road. Each of these drain points is classified as delivering or not delivering. No estimate of fractional delivery is made because there is insignificant hillslope sediment storage in locations where there is a clear connection to the channel under most circumstances. GRAIP identifies drain points at which sediment is delivered to a channel and estimates how much sediment is delivered to the channel at a given drain point in kilograms per year.

Drain Point Analysis

Highlighted GRAIP Predictions:

- Total sediment production (sediment eroded off of road surfaces) from all roads in the Middle Fork Payette Sub basin 3,918 tons/year
- Total eroded road sediment that reaches a stream equals 790 tons/year
    - 84% (663 tons/yr.) occurs on National Forest System roads, 16% (126 tons/yr.) occurs outside the Boise National Forest boundary on state or private lands
    - 20% of all sediment produced reaches a channel
    - 17% of effective road length delivers sediment to a channel
- 17,203 drain points were observed and recorded by field crews, 2,135 of which are actively delivering sediment to streams
    - 12% of drain points deliver 100% of all road sediment to streams
    - 1% of drain points deliver 50% of all road sediment to streams
    - 6% of drain points deliver 95% of all road sediment to streams

The road inventory information can answer many questions about the function and design of the road drainage system and how well the best management practices functioning. Table 2 and figure 2 show that ditch relief culverts are the most likely to deliver sediment to the stream, deliver the largest amount and connect the most road

[1] For this analysis, a base erosion rate of 17.8 kg/m/yr. of road direction per unit of slope was used. This figure is based on data collected from 2010 through 2012 at road sediment catchment basins located within the Middle Fork Payette River sub basin in the Lightning Creek sub-watershed. Further monitoring of sediment trapped by these basins over multiple years will help calibrate this figure over an extended period of time to account for variations in annual precipitation. See Appendix B for further details on the erosion plot study.

length proportionally. Stream crossings connect to the stream by definition, but in some cases broad based dips and non-engineered features are located at or adjacent to stream crossings. Diffusely drained roads are a common feature on low standard roads and they deliver only 4% of the total from roads.

Table 2. Summary of sediment production and delivery at drain points. Percent sediment delivery is the delivery divided by the total production. Percent connected length is the fraction of road length associated with that drain type that is connected to the channel.

Drain Type	Count	Total Sediment Production (T/yr)	Total Sediment Delivery (T/yr)	% Sediment Delivery	Connected Length (m)	% Connected Length[2]
Broad Based Dip	2,147	995.8	102.2	10%	155,603	11%
Diffuse Drain	4,551	369.2	13.0	4%	314,964	2%
Ditch Relief Culvert	2,486	705.0	266.2	38%	177,838	37%
Lead Off Ditch	137	39.4	9.7	24%	9,070	34%
Non-Engineered	1,810	634.6	118.4	19%	95,831	21%
Stream Crossing	657	131.9	131.9	100%	34,884	100%
Sump	133	48.6	0.0	0%	9,782	0%
Water bar	5,282	993.8	148.7	15%	140,491	13%
All Drains	**17,203**	**3918.4**	**790.1**	**20%**	**938,462**	**17%**

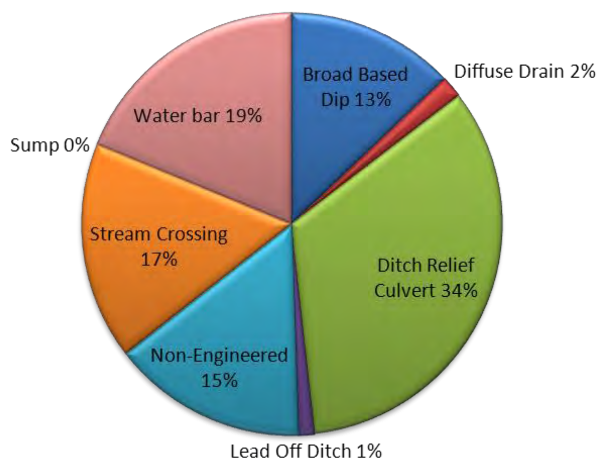

Figure 2. Distribution of total sediment delivered to a channel by drain type. Broad based dips and non-engineered drainage may occur at or near stream crossing locations, so the stream crossing delivery appears smaller than expected.

Table 3. Summary of drain point connectivity to streams and observed active sediment delivery at drain points.

Drain Type	Count	Drain Points Actively Delivering Sediment to Stream	% of Drain points Actively Delivering Sediment to Stream
Broad Based Dip	2,147	218	10%
Diffuse Drain	4,551	107	2%
Ditch Relief Culvert	2,486	815	33%
Lead Off Ditch	137	39	28%
Non-Engineered	1,810	340	19%
Stream Crossing	657	657	100%
Sump	133	0	0%
Water bar	5,282	469	9%
All Drains	17,203	2,135	12%

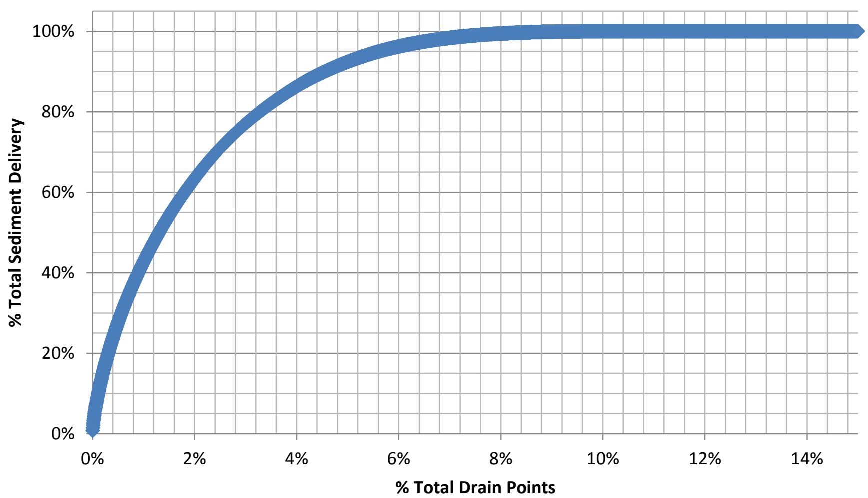

Figure 3. Percentage of the total amount of fine sediment delivered to a stream channel explained by the percentage of the total quantity of drain points.

Areas of High Sediment Delivery to Streams

Highlighted GRAIP Predictions:

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- Most sediment delivery from roads to streams is occurring on Maintenance Level 2 and above roads
    - Much of the road-stream connectivity takes place where roads run parallel to streams or within the immediate vicinity of a road/stream intersection
    - Level 1 roads generally appear to be low-impact
- Roads with excessive sediment delivery include:
    - NFS road 698 between the Sixmile Road Bridge (Jnct. 698 and 670) and Boiling Springs.
    - NFS roads 668 and 669 in the Anderson Creek drainage.
    - NFS road 696 in the Scriver Creek drainage.

Photo 2. FR 696 alongside West Fork Scriver Creek has frequent road-stream connectivity and high rates of road surface erosion.

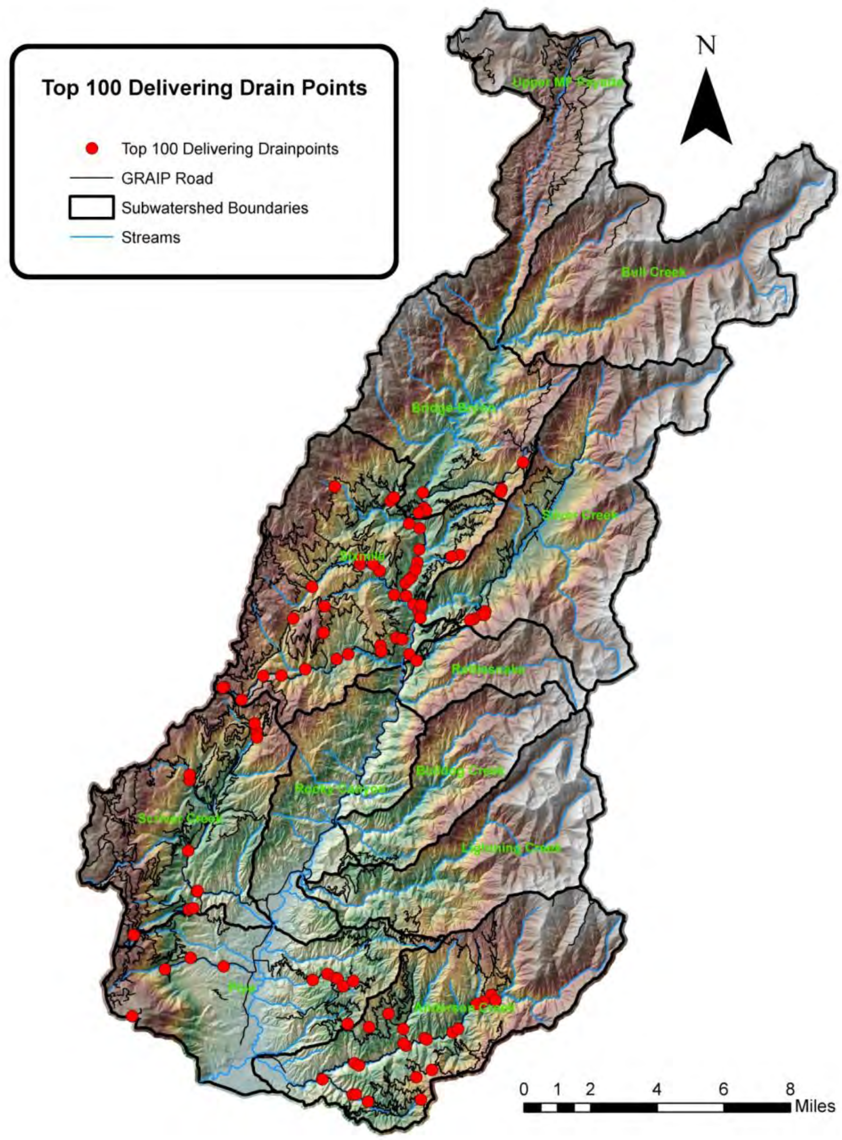
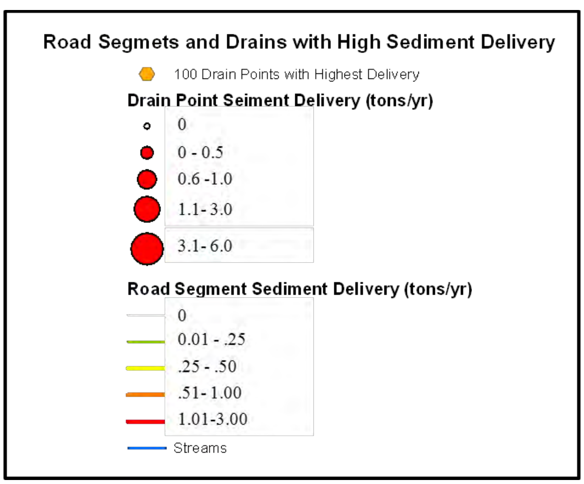


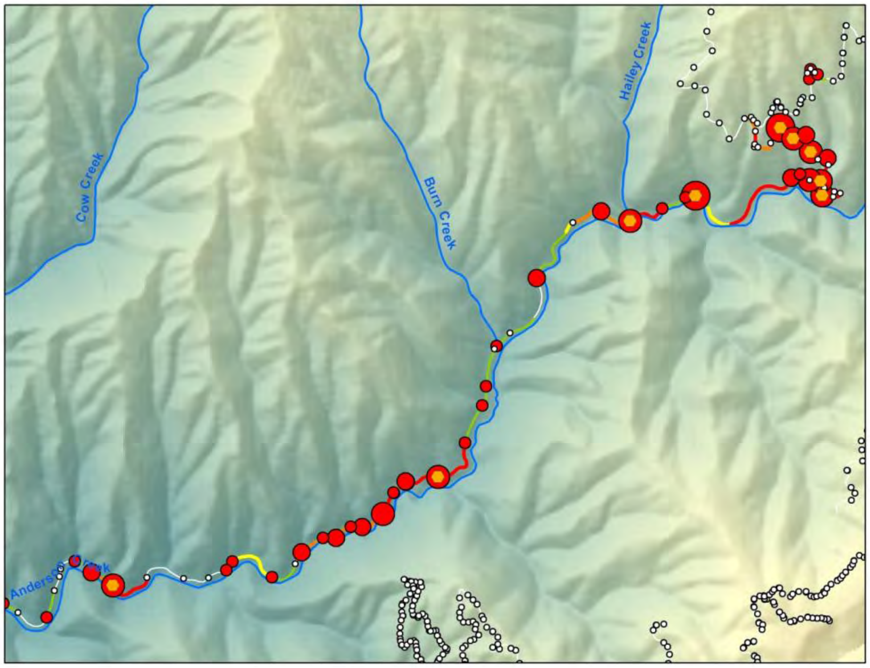
Figure 4. Map of top 100 drain points in terms of highest annual sediment delivery are emphasized**.**

Table 4. Fine sediment delivery values for road segments displayed in Figure 4 including percentage of total annual sediment delivery for the entire sub basin.

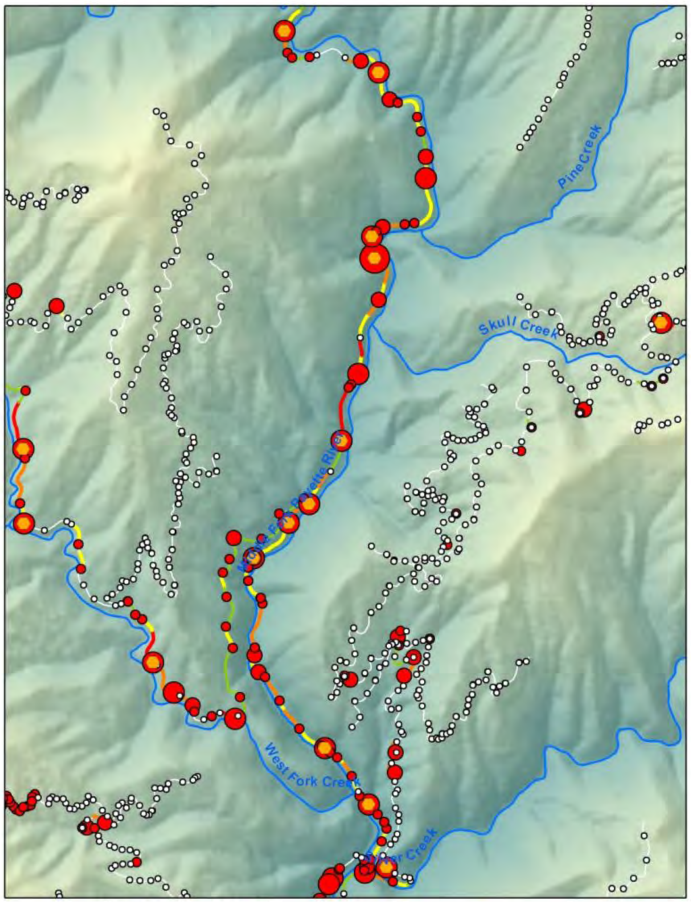
Figure 4 Map	Delivering Drain Point Count	% of Total Delivering Drain Points	Length of road Delivering (mi)	% of total Delivering Road Length	Sediment Delivery to Stream (ton/yr.)	% of Production that Delivers	% of Total Annual Sediment Delivery
A	42	13%	3.6	42%	35.1	51%	4%
B	127	17%	8.1	30%	76.3	35%	10%
C	70	15%	3.5	21%	27.5	33%	3%
Total	239	15%	15.2	29%	139.0	37%	18%

Figure 5. Maps of fine sediment delivery to channels by road segment and drain point. As indicated in the legend below, the road line is colored to indicate the predicted mass of fine sediment that is produced on the road and delivered to the channel. The size and color of the circle indicate the accumulated mass of sediment delivered through each drain point. All red circles indicate a drain point that is actively delivering sediment to streams while small white points represent a drain point not connected to the stream (see legend below). See Table 4 for length of sediment-contributing road segments and amount of fine sediment delivery for each displayed road.



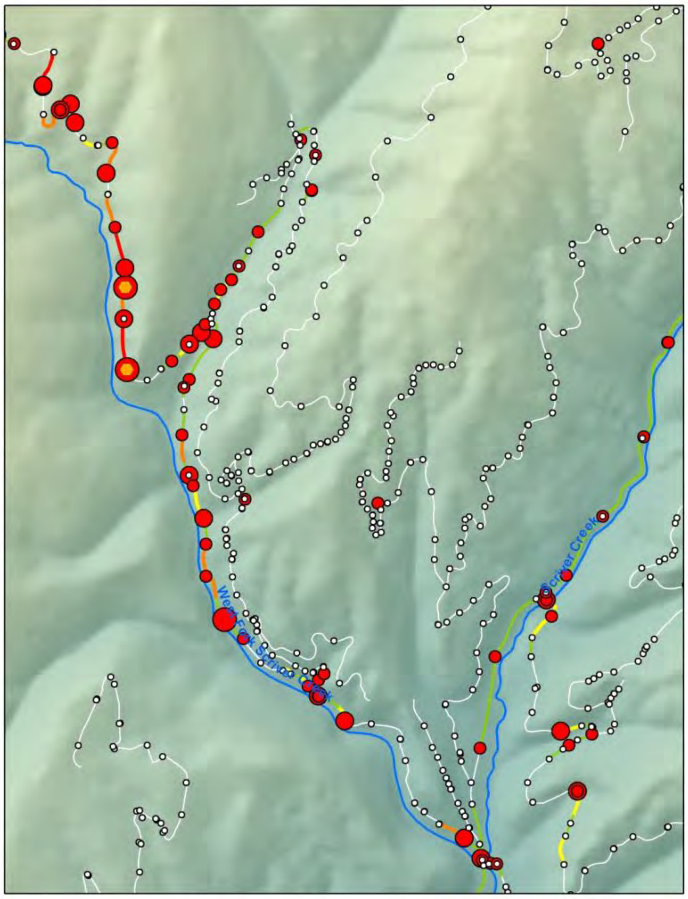


A) The portions of FR 668 displayed in this graphic are found along Anderson Creek. 9 of the top 100 delivering drain points are found in this area. The delivering drain points in this graphic are contributing 4% of all road sediment delivered to the Middle Fork Payette River.



B) Portion of the FR 698 between Silver Creek and Boiling Springs. This road follows the Middle Fork Payette River. 15 of the top 100 delivering drain points are found along this stretch. The delivering drain points are contributing 10% of all road sediment delivered to the Middle Fork Payette River.

Middle Fork Payette River Road Inventory (GRAIP) Report
Boise National Forest



C) The portions of FR 696, FR 696A, FR 696A1, and FR 693Q shown in the below graphic are contributing about 3% of total sediment delivered in the Middle Fork Payette River. Decommissioning treatments have been appropriately arranged for these road segments as part of the Scriver Creek Integrated Restoration Project.

Road Segment Analysis
Road Segment Analysis
Highlighted GRAIP Predictions:

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- 8% of road length delivers 100% of road sediment to streams.
    - <2% of road length delivers 50% of sediment.
    - 5% of road length delivers 90% of sediment.
- 17% of recorded road segments deliver 100% of road sediment to streams.
    - 3% of road segments deliver 50% of sediment.
    - 10% of road segments deliver 90% of sediment.
- 64% of road surfaces were observed to be primarily made up of native material[2]
    - 7% had a crushed rock surface
    - 27% of road surfaces were dominated by vegetation, though were likely originally constructed with a native material surface.
- 49% of flow path length was recorded to have greater than 25% vegetation cover, dramatically reducing sediment production.

Photo 3. *Left:* Matt Taylor inspecting a gullied road surface on Rd 695F. *Top right:* Jim Bitzenburg surveying a waterbar road 695A. *Bottom right:* Saturated and rutted road surface of FR 695A**.**

[2] These numbers represent the road surface at the time GRAIP data was collected. Extensive road surfacing has been conducted along the 698 and 693 roads during 2010-2013.

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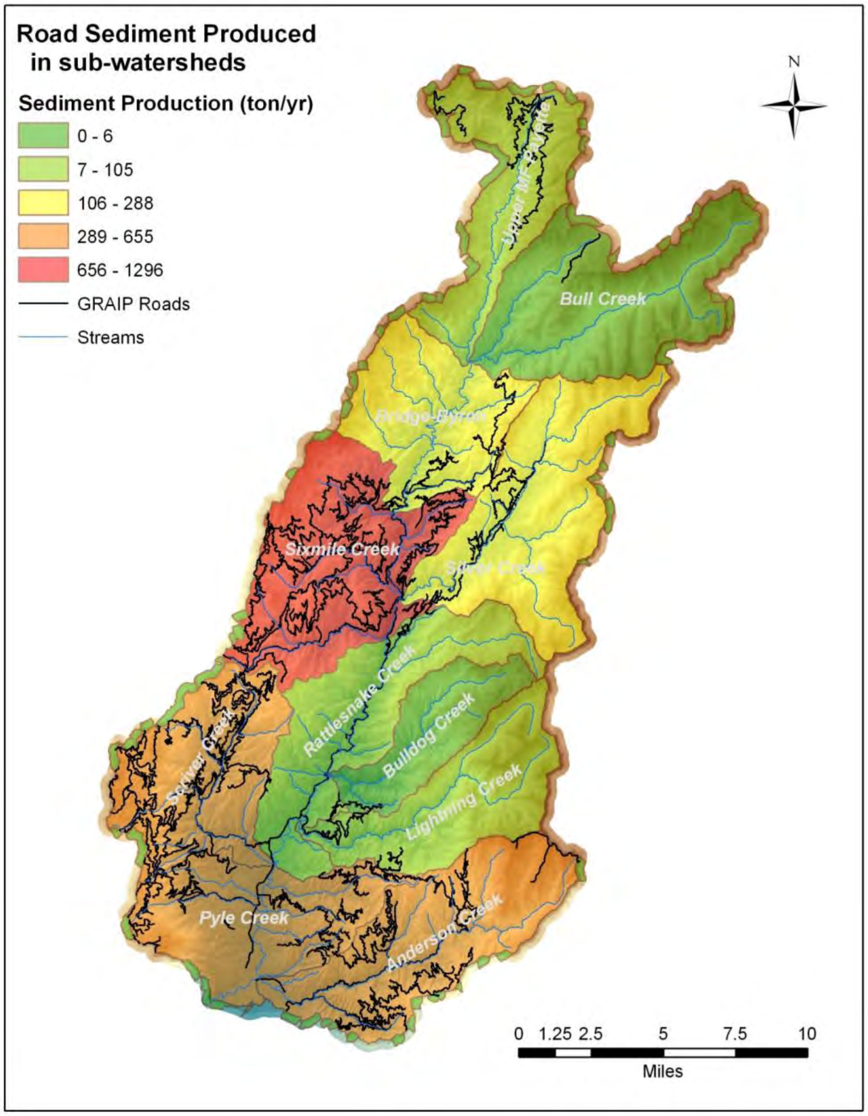
Figure 6. Middle Fork Payette River area map of sediment produced by erosion from the road surface by sub-watershed.



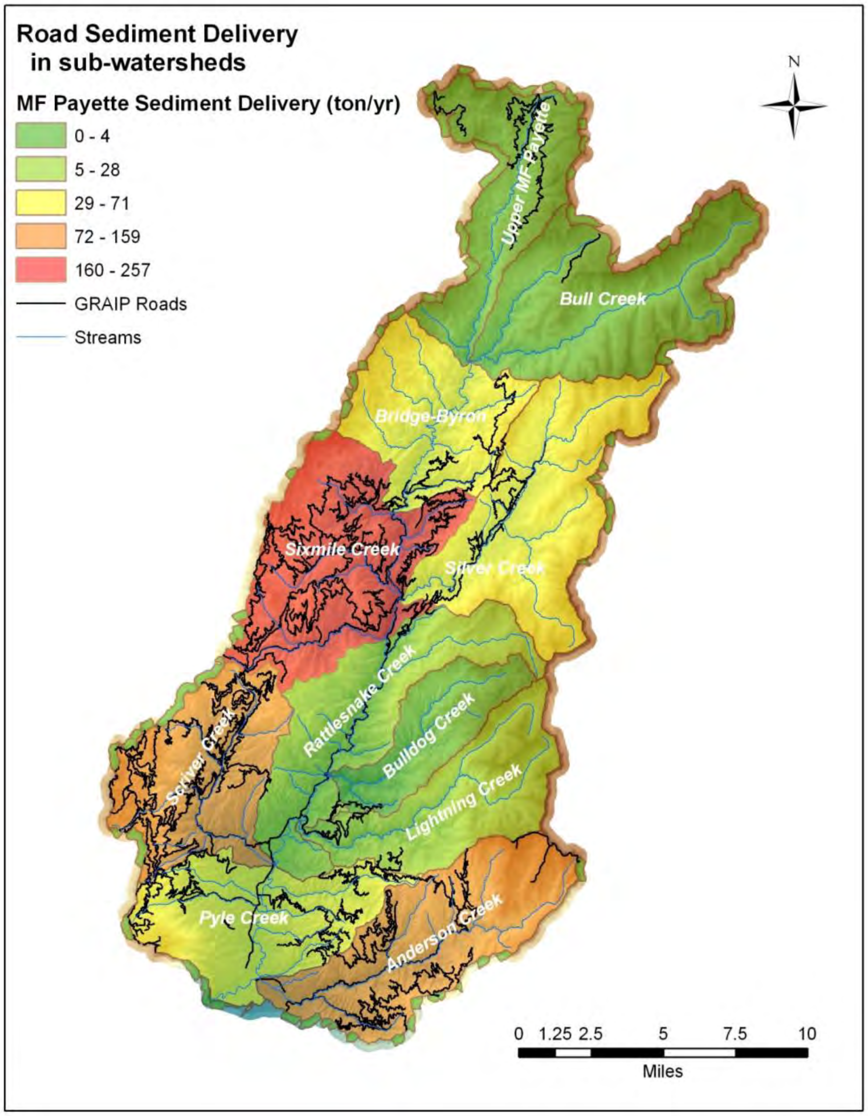


Figure 7. Middle Fork Payette River area map of sediment delivered to stream channel the road surface by sub-watershed.

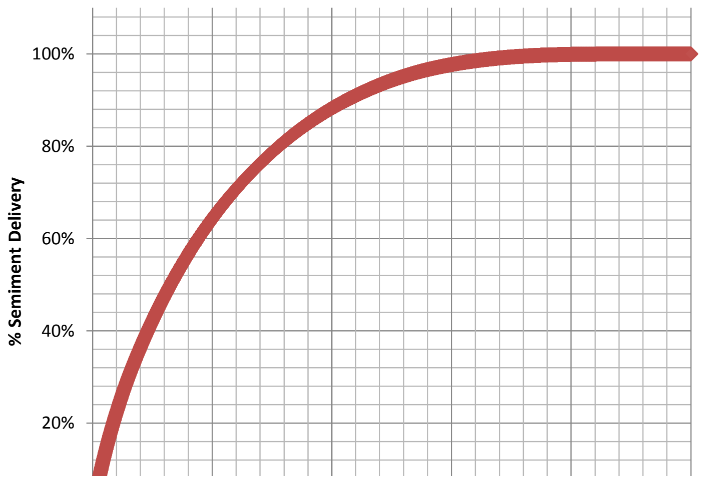


Figure 8. Percentage of the total amount of fine sediment delivered to a stream channel explained by the percentage of the total road length.

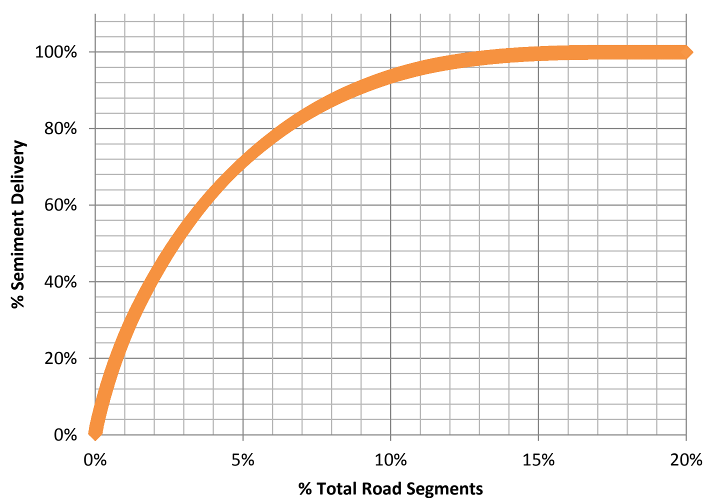


Figure 9. Percentage of the total amount of fine sediment delivered to a stream channel explained by the percentage of the total quantity of road segments.

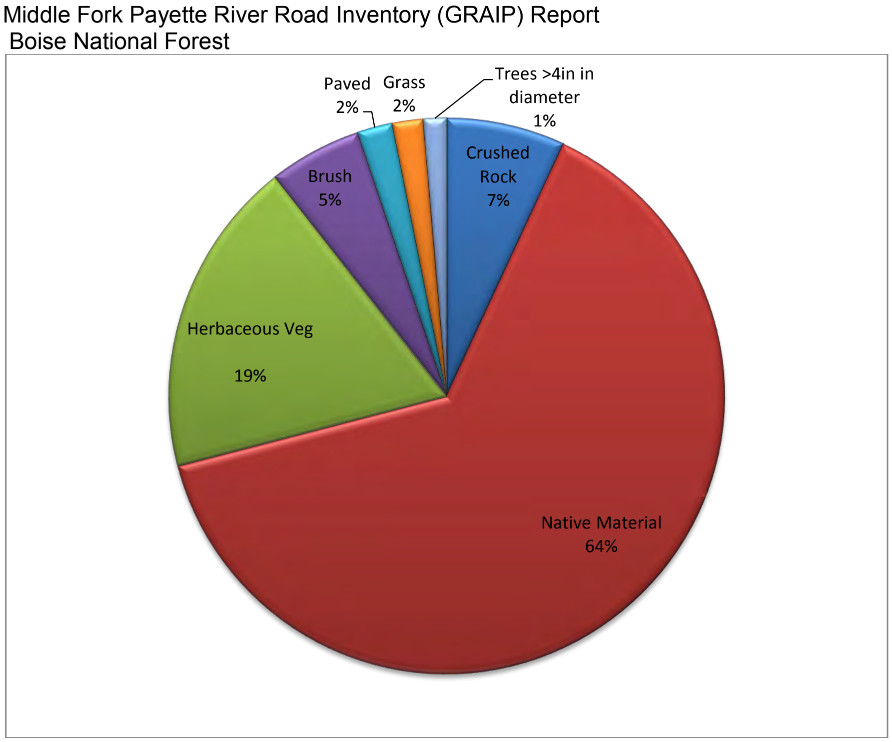


Figure 10. Distribution of road surface types found in the Middle Fork Payette by road length.

Photos 4. The two photos above represent two different road surface types found within the Scriver Creek sub-watershed. *Left:* Herbaceous vegetation surface on FR 695E1. *Right:* Thin layer of crushed rock surface remaining on FR 693.

Vegetation in the flow path, whether a road side ditch, the road surface, or both, is taken into account by the GRAIP model. When the flow path vegetation is observed by the field crew to be greater than 25%, the sediment production rate (amount of sediment eroded off of the road's surface) decreases by a factor of 7. In the Middle Fork Payette Sub basin, 49% of the total flow path length (equivalent to road length) was recorded to have greater than 25% vegetation cover. Relative to other studies and GRAIP road inventories, this figure is rather high. For example, roads inventoried in Bear Valley in 2009 were observed to have greater than 25% vegetation cover in only 27% of total flow path length (Fly et al., 2010). Frequent flow path vegetation can likely be attributed to a high concentration of Maintenance Level 1 roads. Many of these roads have not been graded or otherwise maintained for years, allowing grass, brush, and trees to grow in ditches and on road surfaces. This vegetation has, in many cases, stabilized erosion rates and reduced the impact of chronic sedimentation to streams. However, historic road prisms still pose potential threats to water quality due to risks associated with hillslope and stream crossing failures because old road prisms can intercept and alter surface and subsurface hydrological flow paths and initiate mass wasting events.

2.3 Upstream Sediment Accumulation

Highlighted GRAIP Predictions:

- Total annual accumulated road sediment load is predicted to be 790 tons/yr. and accumulated road sediment rate (road sediment reaching stream per unit area) is estimated at 2.3 tons/mi^2/yr.

GRAIP generates a stream network that is segmented at each channel confluence and each road/stream intersection. For each stream segment, the model calculates the accumulated road sediment load at the downstream end of that segment, including the total accumulated sediment from upstream stream segments (Figure 9). The total predicted amount of accumulated road sediment found in the stream segment nearest to the mouth of The Middle Fork Payette was 790 tons/year. Six Mile Creek has the highest per unit area sediment delivery from roads of 6.4 tons per square mile. Scriver and Anderson Creek have the next highest delivery per area (Table 5).

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Table 5. Stream sediment load values.

Sub-watershed (HUC6)	Total Area (mi^2)	Total Accumulated Road Sediment in Stream (tons/yr.)	Accumulated Road Sediment Rate ($tons/mi^2/yr.$)	Total Accumulated Natural Sediment in Stream[1] (tons/yr.)	Accumulated Reference Sediment Erosion Rate[2] (tons/mi2/yr.)	Increase over the natural reference sediment	GRAIP-Inventoried Road Density (Rd mi/mi^2) [3]
Scriver Creek	29.9	133.2	4.5	1541	52	9%	4.2
Pyle	30.5	71.3	2.3	1554	51	5%	2.3
Anderson	35.1	159.0	4.5	2203	63	7%	2.5
Lightning Creek	25.8	10.9	0.4	1481	57	1%	0.5
Bull Dog	15.9	0	0.0	933	59	0%	0.2
Rattle Snake	10.6	28.1	2.7	542	51	5%	0.6
Six Mile	40.2	256.7	6.4	2743	68	9%	4.0
Silver Creek	40	60.8	1.5	2243	56	3%	0.7
Bridge-Bryon	26.5	64.4	2.4	1827	69	4%	1.1
Bull Creek	37.9	1.8	0.0	1475	39	0%	0.1
Upper MFP	24.8	3.5	0.1	1442	58	0%	1.2

1. BOISED reference rates from Reinig and others 1991
2. BOISED reference rates from Reinig and others 1991
3. Road density of inventoried roads, some private roads not accessed.

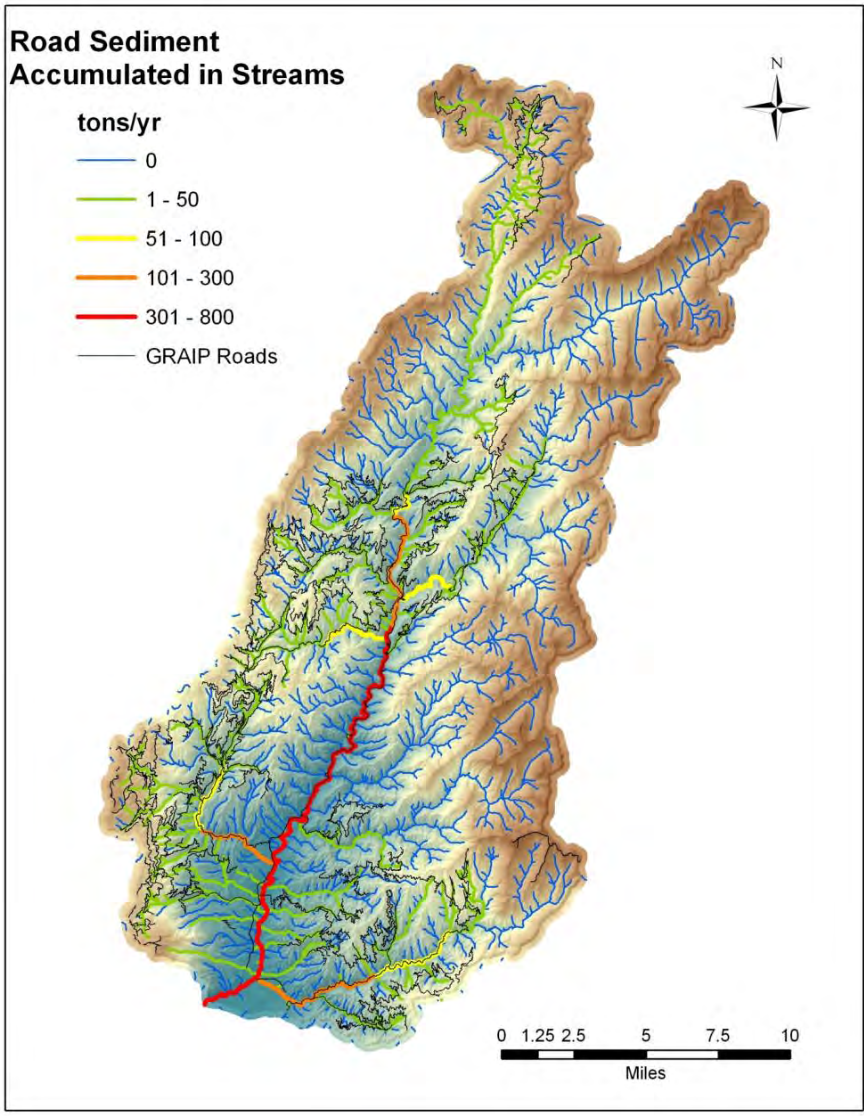

Figure 11. Middle Fork Payette River area map of sub-watersheds and their percentage sediment delivered to stream relative to the rest of the watershed, and stream sediment accumulation from roads.

2.4 Drain Point Condition

Highlighted GRAIP Predictions:

- 10% (1653 total) of drain points were recorded to have condition problems that may require maintenance
- 5% (854 total) of drain points were recorded to have had at least 5 ft^3 of fill material eroded away at the outlet

The GRAIP inventory involves an assessment of the condition of each drain point and a determination of how well it is performing its intended function. Problems with drain point condition are pre-defined for each drain type. Broad based dips are considered to be in poor condition if they are insufficiently outsloped and pond water on the road. Culverts are defined to be in poor condition if they have more than 20% occlusion of the inlet by sediment, substantial inlet crushing, significant rust, or flow around the pipe. Lead off ditches are considered problematic if they have excess deposition or are gullied. Non-engineered features are almost always a problem because they were not designed nor intended to exist. For this exercise, they are considered a problem when caused by a blocked ditch, a gully, a broken outside berm, or a diverted wheel track. They were not evaluated to be problematic when they occurred where a road was outsloped. Stream crossings are considered a problem if they are blocked by sediment or wood, crushed or rusted significantly, incising, scouring or loosing much water from flow around the pipe. Sumps are a problem if they exist unintentionally and pond water on the road surface or cause fill saturation. Water bars that are damaged, under sized, or do not drain properly are defined as problematic. Diffuse drains (outsloped roads) are rarely observed to have drain point problems.

Table 6. Drain point condition problems and fill erosion below drain points.

	Total	Condition problems		Fill Erosion	
Drain Type	Count	Count	Percentage	Count	Percentage
Broad Based Dip	2,147	164	8%	140	7%
Diffuse Drain	4,551	0	0%	17	0.3%
Ditch Relief	2,486	497	20%	96	4%
Lead Off	137	7	5%	0	0%
Non-Engineered	1,810	119	7%	257	14%
Stream Crossing	657	72	11%	53	8%
Sump	133	86	65%	0	0%
Water bar	5,282	708	13%	291	6%
Total	17,203	1653	10%	854	5%

Photos 5. The photos above demonstrate condition problems associated with road drainage infrastructure that exist within the Middle Fork Sub basin. *Top left:* Scott Bergendorf taking measurements at a stream crossing in the Bull Creek Sub watershed that has diverted over the top of the culvert. *Top right:* Fill erosion at a non-engineered drain point on FR 695. *Bottom left:* Fill erosion and infrastructure failure of a log culvert stream crossing on FR 696A. *Bottom right:* Puddles on road and fill saturation at a broad-based dip on FR 693C.

2.5 Stream Crossing Failure Risk

Highlighted GRAIP Predictions:

- 657 stream crossings at roads recorded, 532 constructed with culverts
- Low average Stream Blocking Index (SBI) of 1.6
- Approximately 49,131 yd^3 of fill material are at risk of washing downstream in the event of plugged, overtopped pipes
- 32% (208 out of 657) of stream crossings on roads have the potential to divert stream flow down the road in a major storm event or if plugged

In addition to contributing fine sediment to streams through surface erosion, stream crossings may fail catastrophically when blocked and deliver large sediment pulses to stream channels. Stream crossing failure risks were assessed using the Stream

Blocking Index (SBI, Flanagan et al. 1998). The SBI characterizes the risk of plugging by woody debris by calculating the ratio of the culvert diameter to the upstream channel width and the skew angle between the channel and the pipe inlet.

Field crews recorded a total of 657 stream crossings within the Middle Fork Sub basin. Of these stream crossings, 131 (20%) did not have a round culvert pipe present and were not included in the SBI calculations. These crossings were designed with a bridge, oval pipe, or were decommissioned and excavated, or otherwise did not include a pipe in the design. Risk of pipe plugging does not exist at most of these stream crossing types.

The SBI values for stream crossings within the Middle Fork Sub basin were relatively low with an average value of 1.0 for the 526 assessed stream crossings (Figure 12). The SBI has a range of 1 to 4, where 1 suggests minimal to no risk of blockage. The average pipe to channel width ratio is 1.0 and the median skew angle is less than 25 degrees.

The 480 locations with an SBI less than or equal to 2 typically have pipe to channel width ratios and skew angle combinations that present lower risk. However there are five locations with an SBI of 2 that have a skew angle greater than 75 degrees. The 42 stream crossings with a value of 3 either have moderately undersized pipes with pipe to channel width ratios equal to or less than 0.42, or they have a very high skew angle between the pipe and channel alignment. The four stream crossings with an SBI of 4 have a skew angle of 45 to 75 degrees and are also undersized. One of the crossings with an SBI of 4 has evidence of plugging and diversion in one direction.

Ongoing GIS analysis using the SBI, diversion potential, fill volume and values at risk data will help refine future decisions about where further remediation is required.

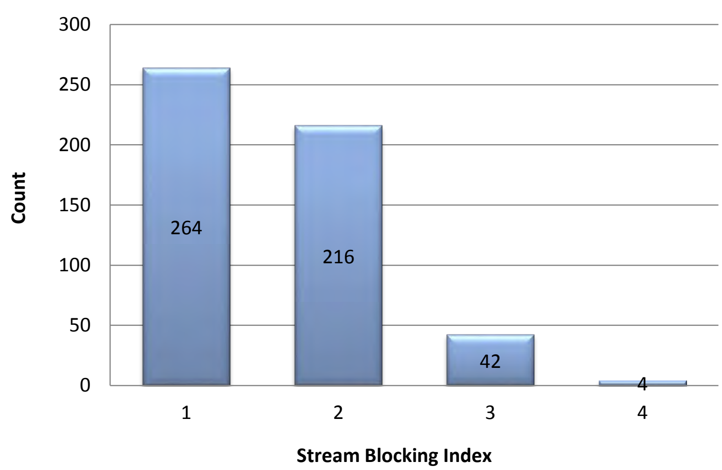

Figure 12. Distribution of Stream Blocking Index (SBI) values. 21 (3%) stream crossing pipes were partially occluded by organic material and sediment and 5 (.7%) were completely occluded by sediment.

The risk of a stream crossing failure can also be viewed in the context of the consequences of failure (Flanagan et al. 1998). A consequence of concern at these stream crossings is the erosion of fill material into the stream channel. The fill material that would likely be excavated in an overtopping type failure was calculated. The prism of fill at risk was modeled as bounded at the base by an area 1.2 times the channel width, with side slopes climbing to the road surface at an angle of 33%. The fill volume at the 527 stream crossings with pipes was approximately 49,131 yd^3.

Photo 6. The three photos above depict a failed stream crossing that where Scriver Creek crosses FR 694 near the headwaters. This crossing showed evidence of being plugged and causing water to flow over the road. This past event (or possible recurring event) eroded away a large amount of fill material, washing it down the channel. The 15 inch diameter pipe is undersized for the estimated 4 foot wide channel at high flow. GRAIP predicted the SBI at this stream crossing to be 3.

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Stream Crossing Type	Count	Average Volume (cu yds)	Total Volume (cu yds)
Steel culvert	401	94	37727
Aluminum culvert	126	91	11405
Steel arch	2	104	208
Log culvert	4	85	340
Total	**533**	**93**	**49679**

A second, and perhaps greater, consequence of concern at failed stream crossings is the diversion of stream flow onto road surfaces and unchannelled hillslopes. Once a crossing becomes occluded and begins to act as a dam, failure can occur in several ways. If the road grade dips into and rises out of the crossing, the failure is likely to be limited to a localized overtopping of the stream crossing. However, if the road grades away from the stream crossing in one or more directions, the flow may be diverted down the road and ditch and onto adjacent hillslopes, where it can cause gullying and/or landsliding (Furniss et al. 1998, Best et al. 1995). This was observed within the Scriver Creek sub watershed during the spring of 2012. A rerouted stream crossing diverted down the 695 road causing slope failure below the road and initiated a debris flow in Hidden Creek that traveled several miles down Scriver Creek depositing a substantial amount of material.

GRAIP addresses this type of issue by classifying the potential for stream crossings to divert stream flow down the adjacent road as one of three options: 1) no potential, 2) potential to divert in one direction, or 3) potential to divert in two directions. In the Middle Fork sub basin, 32% (208 out of 657) of stream crossings on roads had the potential to divert stream flow down the road in one or both directions. The highest risk is from traditional piped stream crossings. 3 stream crossings were observed to have diversion potential in two directions, although one is an excavated stream crossing that is likely to have a low overall risk. Fords and bridges have a low risk and the two pipe arch structures were not at risk of diversion. Taking into account SBI, diversion potential, and fill material volume at risk, stream crossing failure risk in the Middle Fork sub basin is low to moderate.

Table 8. Diversion potential by stream crossing category.

Stream Crossing Type		Diversion Directions			% at Risk
	Count	None	1	2	
Steel culvert round	401	255	144	2	36%
Aluminum culvert	126	80	46	0	37%
Steel arch bottomless	2	2	0	0	0%
Log culvert	4	4	0	0	0%
Natural ford	71	61	10	0	14%
Bridge	26	22	4	0	15%
Excavated	26	24	1	1	8%
Total	657	449	205	3	32%

2.6 Gully Initiation Risk

Highlighted GRAIP Predictions:

- 199 observed gullies.
- 1.5% of all drain points drain to gully. Stream crossings and diffuse drain points are excluded.

Gullying of fill and hillslope material below drain points can be a substantial source of sediment to stream channels. A gully was defined as a linear erosional feature at least ten feet long and six inches deep. 199 gullies were mapped below drain points, not including road and ditch segments that had gullied segments. 187 of the gullied locations were clearly related to road runoff and had mobilized 13,575 cubic yards of material. 13 of these were observed to have stabilized and were no longer actively eroding. 12 gullies were observed to have been caused by hillslope water and mobilized 4,767 cubic yards of material. No estimate of the amount of gully material delivered to the channel was made.

Table 9. Attributes of gullies in the Middle Fork Payette Sub basin including whether they receive road drainage, are actively eroding, their volume and mass.

Road Related	Recent Activity	Count	yds^3	Mass, tons
Yes		**187**	**13,575**	**18,191**
	NOT ACTIVE	13	616	825
	STILL ERODING	174	12,960	17,366
No		**12**	**4,767**	**6,388**
	NOT ACTIVE	4	3,607	4,834
	STILL ERODING	8	1,160	1,554
Totals		**199**	**18,342**	**24,579**

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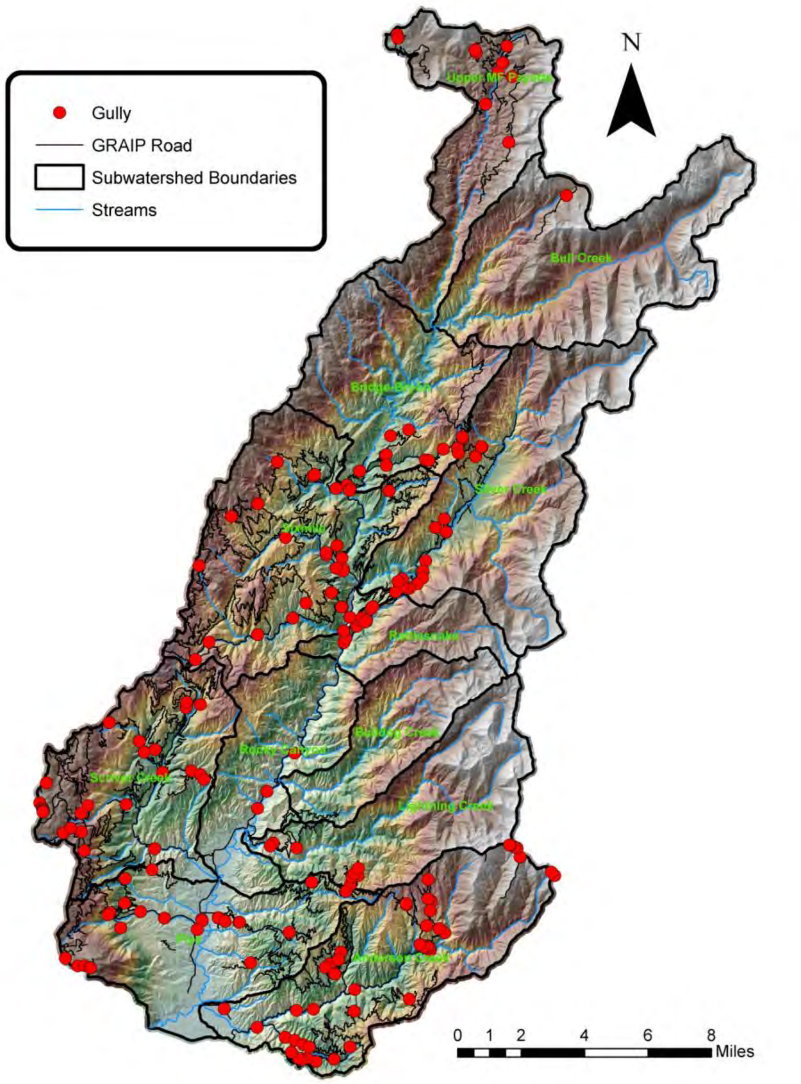

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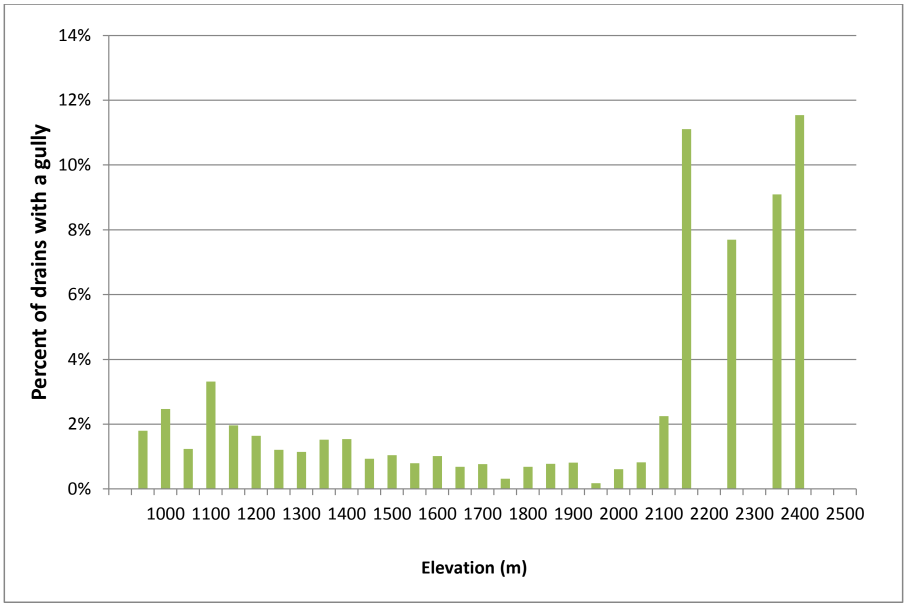


Figure 14. Frequency of gullies in the Middle Fork Payette River sub basin by elevation

Photo 7 (Left) Gully west fork Scriver Creek on 696, this gully is estimated to have 45 cubic feet of erosion and is still actively eroding. *Right:* Two merging gullies on ridge top road 689L5. The feature on the lower left is one of a number of gullies located on the 671 road above Trail Creek.

Gully initiation occurs when the shear stress applied by runoff exceeds the strength of the soil surface on the hillslope. GRAIP computes the Erosion Sensitivity Index (ESI) (Istanbulluoglu et al. 2003), as shown below, at each drainage point.

$ESI = L \times S^2$, where:
L is the road length contributing to the drain point
S is the slope of the hillslope below the drain point.

The average ESI for all drain points was 5.5, with an average contributing road length of 49 m. The average slope of the hillslope below the drain point was 30%. Broad based dips have the highest average ESI and waterbars have the lowest due to differences in contributing road length.

Table 10. The average length and hillslope angle below each drain point type along with the ESI values.

Drain Type	Count	Length (m)	Hillslope (%)	ESI
Broad Based Dip	2,147	72	0.31	8.6
Ditch Relief	2,486	72	0.26	6.6
Lead Off Ditch	137	66	0.19	5.2
Non-Engineered	1,810	53	0.29	6.2
Sump	133	74	0.26	7.0
Waterbar	5,282	27	0.33	3.4
Total	**11,995**	**49**	**0.30**	**5.5**

In many cases ESI values can be compared to a critical ESI threshold (ESIcrit) to identify areas with a high risk of gully formation (i.e., where drain point ESI > ESIcrit). ESIcrit is empirically-derived using inventoried gullies and their probability of occurrence (figure 15). It appears that there is not a sharp ESI threshold in this area but rather a gradual increase above a value of 30 as road length and hillslope increase. The average probability of gully occurrence was observed to be about 1%, while the probability of a gully occurring rose to 6% when ESI exceeded a value of 30.

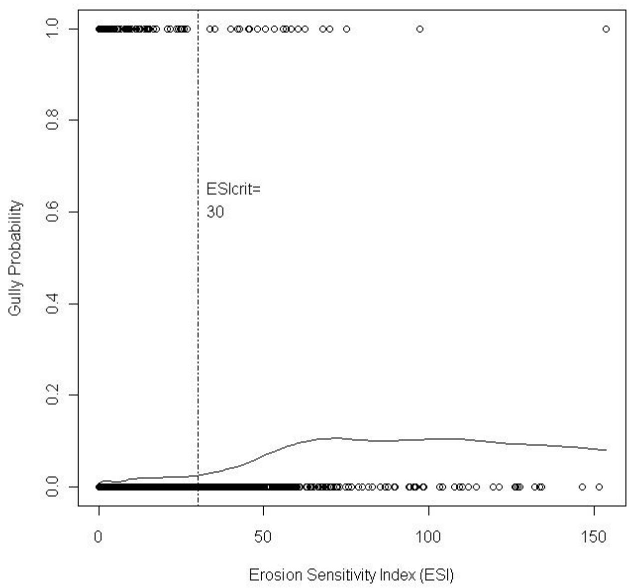


Figure 15. The probability of a gully occurring below a drainpoint as a function of the Erosion Sensitivity Index (ESI). The average ESI was 1%, while the value above the ESI value of 30 was 6%.

2.7 Landslide Risk

Highlighted GRAIP Predictions:

- 119 total landslides (76 of 119 are road related).

Photo 8. Large landslide of fill slope on a spur road off of 669.

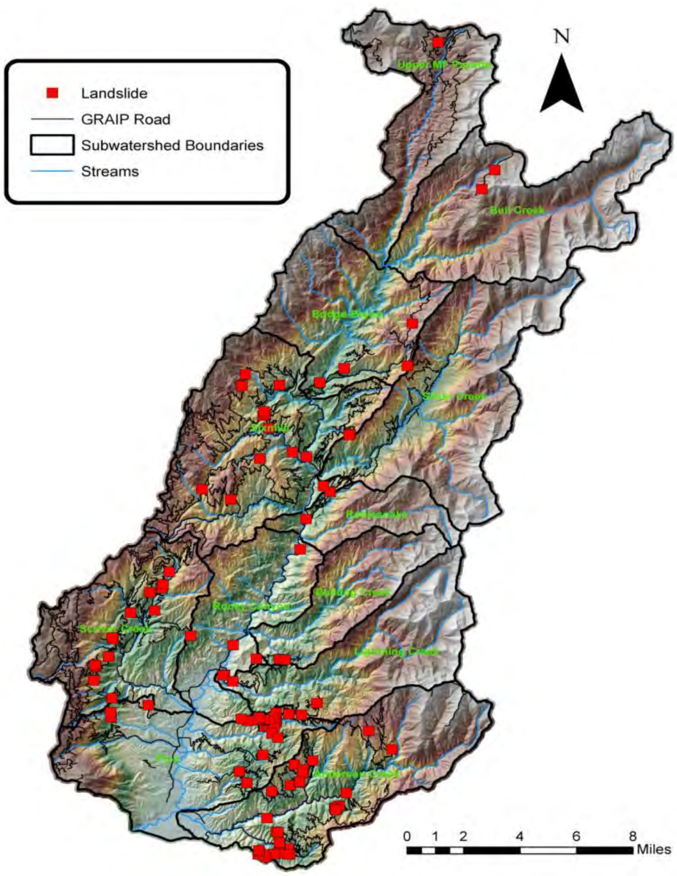


Figure 16. Map of landslides in the Middle Fork Payette sub watershed.

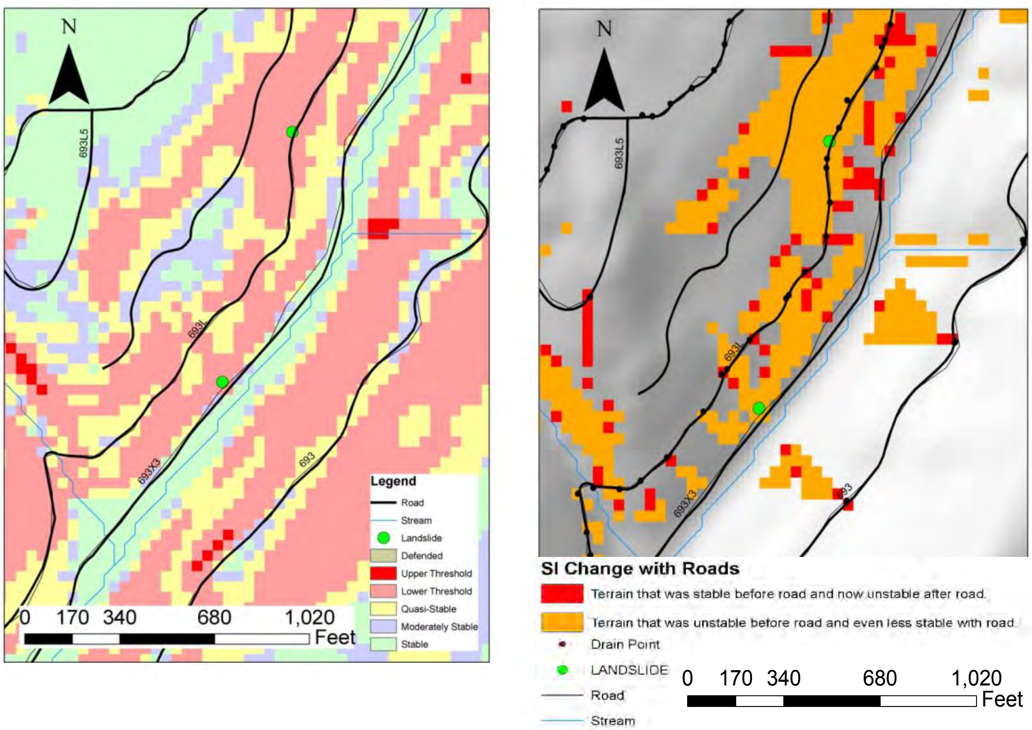
Landslides were mapped in the field using a measuring tape to determine volume. The attributes of the landslide were inventoried including approximate age, relation to road, and location relative to the road. Of the 119 landslides collected 76 were road related. Of the 166,687 yd^3 that were observed at the 119 locations, 117,373 yd^3 (70%) was associated with road drainage Table 11. This means the road contributed to the landslide by interfering with the natural stability of the hillslope. This was identified by observing the failure of the cutslope or fillslope directly above or below the road. The majority of the observed road related landslides and the volume occurred on the fillslope of the roads although size of the average hillslope landslide was nearly three time the volume. Vegetation cover was used to estimate landslide age suggesting that 20% of landslides were less than 5 years old, 55% were less than 10 years old and 25% were less than 15 years old

Table 11. Attributes of landslides including their location, whether they receive road drainage and, their volume and mass.

Location	Road related	Count	Average Volume cu yd.	Total Volume cu yd.	Mass (tons)
CUTSLOPE		23	667	15,334	20,548
	NO	5	1,646	8,229	11,027
	YES	18	395	7,105	9,521
FILLSLOPE		53	1,481	78,503	105,196
	NO	7	1,414	9,901	13,268
	YES	46	1,491	68,602	91,929
HILLSLOPE		38	1,868	71,002	95,145
	NO	28	1,098	30,740	41,193
	YES	10	4,026	40,262	53,952
SLUMP		5	370	1,848	2,476
	NO	3	115	344	461
	YES	2	752	1,504	2,015
Total		119	1,401	166,687	223,365

The risk of shallow landslide initiation is predicted using SINMAP 2.0 (Pack et al., 2005, http://hydrology.neng.usu.edu/sinmap2/), then modified to account for contributions of road runoff. An example from NFSR 693L is shown in Figure 17 to illustrate the change in risk in an area where the inherent landslide risk is high. This risk is assessed by referring to an index referred to as the Stability Index (SI). SINMAP was run initially to determine the intrinsic stability (SI) of the slopes over which the road traverses and to identify locations that are at high risk of failure without a road (Figure 17a).

Figure 17. Stability index for hillslopes in the vicinity of Road NFSR 693L.
a) (left) SI value for hillslopes in a un-roaded condition. **b)** (right) Negative changes in SI due to the addition of road drainage.



A second stability index run was performed to address the effects of road water contribution to drain points on the road network. This second stability index run is referred to as the Stability Index Combined (SIC) because it accounts for both the naturally inherent risk of hillslope failure in a landscape and the added risk from roads. Slope stability analysis is only available for the Scriver Creek sub watershed at the time of writing as the detailed SinMap analysis for the MF Payette sub basin is incomplete.

3.0 Summary and Conclusion

The BNF and the RMRS initiated a road inventory project to include all roads in the Middle Fork Payette River sub basin from 2009-2011. Funding was provided through the EPA. Field crews inventoried road segments throughout the Middle Fork Payette drainage while a data manager and a GIS technician processed and analyzed the data that was collected in the field. The GRAIP model was used to predict the level of impact/risk that existing roads posed on streams.
Inventory data was collected on over 520 miles of road, including 17,203 drain points, by field crews during three field seasons. An investment made in crew training and oversight paid off in the form of well documented precision and accuracy measures. Study objectives were identified as outlined in Section 2.0 of this report. These objectives were met and the questions posed were answered as shown below.

1. What is the existing level of fine sediment delivery from roads to streams in the Middle Fork Payette Watershed?
a. How does the contributed sediment from roads compare to natural reference sediment levels?

The length of the sampled road that was hydrologically connected to streams totaled 113 mi out of the 583 mi of inventoried road (19%). The model predicted that the existing level of fine sediment delivery from roads to streams amounts to 790.1 tons annually, which is 20% of the predicted annual fine sediment production total of 3,918.4 tons. Road sediment that accumulates in the stream network annually is predicted by the model to be 790.1 tons. The accumulated road sediment per unit area for the entire Middle Fork of the Payette is predicted to be 2.3 tons/mi2/year. Compared to the watershed's natural reference sediment accumulation rate of 52 tons/mi2/yr., added road sediment yields a 4% increase.

There is considerable variability in the modeled sediment delivery between the individual sub basins and how that relates to background. Scriver and Six Mile Creeks are predicted to be 9% above the BOISED background, while Bull Dog, Bull Creek and the Upper Middle Fork Payette were not significantly impacted by road sediment with 1% or less above background.

2. Where are the locations of highest sediment delivery from roads to streams?
a. Can these sites be reconstructed to eliminate or minimize delivery?

As indicated in Figures 5, locations of high sediment delivery within the Middle Fork Payette are relatively localized with some of the highest delivery in valley bottom road locations. This is in part because historically road location was confined to valley bottoms by the topographic and engineering constraints. The sediment delivery is also concentrated in a few locations. 12% of all drain points and 8% of road length delivers all of the sediment to streams. This insight can help management prioritize the largest sediment targets first. The 668 and associated roads in Anderson Creek, the 698 road in Silver Creek and the 696 in the West fork of Scriver Creek have 26 of the top 100 delivering drain points in the study area accounting for 18% of the basin total delivery. Road-stream connection often occurs at or near live stream crossings on roads. Although these predicted locations of high sediment delivery are based on thorough field observations and careful data processing, more thorough field surveys of the indicated road segments and drain points need to be completed in order to design effective management plans. A few such field observations have already proven helpful in calibrating the severity of problematic features and assessing the need for remediation. Reconstruction of such sites is possible and feasible in most cases. In order to decrease sediment delivery, road improvements may involve the addition of more frequent road drainage features, leaving a shorter distance between features. This would decrease the energy of concentrated flow to individual drain points, thus shortening the distance that water and sediment travels down the hillslope. Treatments may also include re-surfacing the road with a crushed rock aggregate or another type of surface which is less erosive. In the case of NFSR 696, plans are being prepared to decommission this road and reroute it farther from the stream.

As a whole, these results indicate that specific roads within the Middle Fork Payette do pose some risk to water quality and associated beneficial uses. It is also evident that a feasible amount of project work could eliminate a substantial portion of this risk.

By making improvements to about 11 miles of road, up to 50% of fine sediment delivery from roads could be addressed. Reconstructing 70 miles of road could address road segments that are responsible for all of the sediment delivery.

The incidence of road related landsliding (76 occurrences) was observed to be lower than expected. Road related gully occurrence was more common but the threshold for gully initiation was relatively high compared to other locations. Future restoration work can reduce the drainage to active gullies and landslides that deliver chronic sediment to channels. The ESI threshold will inform future road design work on steep unstable granitic hillslopes to minimize the risk of gully occurrence.

With the benefit of the GRAIP inventory data future work could also be effective in greatly reducing many of the hydrogeomorphic impacts and risks that these roads pose to water quality and associated beneficial uses. This analysis will allow forest managers to efficiently prioritize resource restoration plans based on site-specific data.

4.0 References

Best, D.W., Kelsey, H.M., Hagans, D.K., and M. Alpert. 1995. Role of fluvial hillslope erosion and road construction in the sediment budget of Garret Creek, Humboldt County, California in Geomorphic Process and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. Nolan, K.M., Kelsey, H.M., and D.C. Marron, editors. USGS professional paper #1454. pp. m1-m9.

Black, T. A., Cissel, R. and Luce, C. H. 2012. The Geomorphic Road Analysis and Inventory Package (GRAIP) Volume 1: Data Collection Method. Gen. Tech. Rep. RMRS-GTR-280WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Black, T. A. and Luce, C. H. 2013. Measuring Water and Sediment Discharge from a Road Plot with a Settling Basin and Tipping Bucket. Gen. Tech. Rep. RMRS-GTR-287.

Middle Fork Payette River Road Inventory (GRAIP) Report
Boise National Forest
Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Black, T.A., Luce, C.H., Monschein, E., and L. Woodruff. 2009. Geomorphic Road Analysis and Inventory Package (GRAIP) Field Collection Activities: Quality Assurance Project Plan (QAPP). USDA Forest Service Rocky Mountain Research Station and U.S. Environmental Protection Agency Region 10 and Headquarters 303 (d) Program Offices.

Cissel, R. M., Black, T. A., Schreuders, K. A. T., Prasad, A., Luce, C. H., Nelson, N.A., Tarboton, D.G., and Nelson, N. A. 2012A. The Geomorphic Road Analysis and Inventory Package (GRAIP) Volume 2: Office Procedures. Gen. Tech. Rep. RMRS-GTR-281WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Flanagan, S.A., Furniss, M.J., Theisen, S., Love, M., Moore, K., and J. Ory. 1998. Methods for Inventory and Environmental Risk Assessment of Road Drainage Crossings. USDA Forest Service Technology and Development Program 9877-1809-SDTDC. 45 pp.

Fly, C. K. Grover Wier, J. Thornton, and T. Black. 2011. Bear Valley Road Inventory (GRAIP) Report. Bear Valley Category 4b Assessment. Lowman Ranger District, Boise National Forest. Lowman, ID. 44p.

Furniss, M.J., Love, M., and S.A. Flanagan. 1997. Diversion Potential at Road Stream Crossings. USDA Forest Service Technology and Development Program 9777-1814-SDTDC. 12 pp.

Istanbulluoglu, E., Tarboton, D.G., Pack, R.T., and C.H. Luce. 2003. A sediment transport model for incision of gullies on steep topography. Water Resources Research. 39(4): 1103-1117.

Jones, J.A. and G.E. Grant. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon, Water Resources Research, 32, 959-974.

Luce, C.H. and T.A. Black. 1999. Sediment production from forest roads in western Oregon. Water Resources Research. 35(8): 2561-2570.

Madej, Mary A. 2001. Erosion and Sediment Delivery Following Removal of Forest Roads, Earth Surface Landforms and Processes, 26(2) pp.175-190.

Pack, R. T., Tarboton, D.G., Goodwin, C.N., and A. Prasad. 2005. SINMAP 2.0 A Stability Index Approach to Terrain Stability Hazard Mapping, technical description and user’s guide for version 2.0, Utah State University.

Prasad, A. 2007. A tool to analyze environmental impacts of road on forest watersheds. MS Thesis. Utah State University, U.S.A.

Prasad, A., Tarboton, D.G., Schreuders, K.A., Luce, C.H., and T.A. Black. 2007. GRAIP1.0 Geomorphic Road Analysis and Inventory Package: A tool to analyze the environmental impact of roads on forested watersheds. Tutorial and Reference Manual. http://www.engineering.usu.edu/dtarb/graip.

Shapiro, D. and associates. 2000. Bear Valley Watershed Analysis. USDA Forest Service, Boise National Forest, Lowman Ranger District. 262 pp.

Reinig, L., Beveridge, R.L., Potyondy, J.P., and F.M. Hernandez. 1991. BOISED User’s Guide and Program Documentation. USDA Forest Service, Boise National Forest. V. 3.01.

Middle Fork Payette River Road Inventory (GRAIP) Report
Boise National Forest
Wemple, B.C., Jones, J.A., and Grant, G.E. 1996. Channel network extension by logging roads in two basins, western Cascades, Oregon, Water Resources Bulletin, 32, 1195-1207.

Appendix A: Glossary of Selected Terms

Below is a list of terms, mostly of drainage point types, but also of some other commonly used terms, for the purpose of clarification. Adapted from Black, et al. (2011), Fly, et al (2010), and Moll (1997).

Broad based dip. ***Constructed:*** Grade reversal designed into the road for the purpose of draining water from the road surface or ditch (also called dip, sag, rolling grade, rolling dip, roll and go, drainage dip, grade dip). ***Natural:*** A broad based dip point is collected at the low point where two hillslopes meet, generally in a natural swale or valley. This is a natural low point in the road that would cause water on the surface of the road to drain out of the road prism.

Cross drain. This is not a feature collected specifically in GRAIP, and it can refer to a number of other drainage features. It is characterized by any structure that is designed to capture and remove water from the road surface or ditch. Ditch relief culverts, waterbars, and broad based dips can all be called cross drains.

Diffuse drain. This is a point that is characterized by a road segment that does not exhibit concentrated flow off the road. Outsloped roads or crowned roads often drain half or all of the surface water diffusely off the fillslope. Although collected as a drain point, this feature is representative of an area or a road segment rather than a concentrated point where water is discharged from the road prism. A drop of water that lands on a diffuse road segment will not flow down the road or into the ditch, but more or less perpendicular to the centerline off the road surface and out of the road prism. Also called sheet drainage or inter-rill flow.

Ditch relief culvert. This drain point is characterized by a conduit under the road surface, generally made of metal, cement, or wood, for the purpose of removing ditch water from the road prism. This feature drains water from the ditch or inboard side of the road, and not from a continuous stream channel.

Flow path. This is the course flowing water takes, or would take if present, within the road prism. It is where water is being concentrated and flowing along the road from the place where it enters the road prism, to where it leaves the road prism. This can be either on the road surface, or in the ditch.

Lead off ditch. This drain point is characterized by a ditch that moves flow from the roadside ditch and leads it onto the hillslope. Occurs most often on sharp curves where the cutslope switches from one side of the road to the other. Also known as a daylight ditch, mitre drain, or a ditch out (though this term can also describe other types of drainage features).

Non-engineered drainage. This drain point describes any drainage feature where water leaves the road surface in an unplanned manner. This can occur where a ditch is dammed by debris, and the water from the ditch flows across the road, where a gully crosses the road, where a wheel rut flow path is diverted off the road due to a slight change in road grade, or where a berm is broken and water flows through. This is different from a diffuse drain point, which describes a long section of road that sheds water without the water concentrating, whereas this point describes a single point where a concentrated flow path leaves the road.

Orphan drain point. This is any drain point that does not drain any water from the road at the time of data collection. Examples include a buried ditch relief culvert, or a water bar that has been installed on a road that drains diffusely.

Stream crossing. This drain point is characterized by a stream channel that intersects the road. This feature may drain water from the ditch or road surface, but its primary purpose is to route stream water under or over the road via a culvert, bridge, or ford. A stream for the purposes of GRAIP has an armored channel at least one foot wide with defined bed and banks that is continuous above and below the road and shows evidence of flow for at least some part of most years.

Sump. ***Intentional:*** A closed depression where water is intentionally sent to infiltrate. ***Unintentional:*** Any place where road water enters and infiltrates, such as a cattle guard with no outlet, or a low point on a flat road.

Waterbar. This drain point is characterized by any linear feature that is perpendicular to the road that drains water from the road surface and/or ditch out of the road prism or into the ditch. Waterbars may be constructed by dipping the grader blade for a short segment, or adding a partly buried log or rubber belt across the road. Some road closure features may also act as a waterbar, such as a tank trap (also known as a closure berm or Kelly hump). Cattle guards that have an outlet that allows water to flow out are also considered to be water bars. These features may also be known as scratch ditches if they drain water into the ditch.

Appendix B: Sediment Plot Results

To obtain local calibration for the GRAIP model, erosion plots were installed using the method outlined in Black and Luce 2013. These plots were 80 meters in road length, between 5 to 6% slope and are located on native surface forest roads that receive low to moderate levels of light vehicle traffic. The roads are built on granitic parent material. Plots were installed in September of 2009 and data collection is ongoing. There are three and a half years of data available as of this writing.

Commented [UFS1]: Add citation

Photo 9. Typical road plot on left and sediment tank on the right.

Weather observations were obtained from at a weather station located at the US Forest Service Garden Valley Work Center located approximately 9 miles from the sediment plot locations along the Lightning Creek road (NFS road 611). The average annual precipitation between 1949 and 2012 for the Garden Valley area was 24.4 inches per year with the majority falling as winter snow. Rainfall that arrives during the spring and summer months often is delivered by convective storms. This precipitation has a higher potential to cause erosion and sediment transport as it is delivered over a short period of time, typically less than an hour. The USFS Garden Valley weather station typically receives a total of 5.0 inches of precipitation in the months from May through September. During the period of study beginning in the 2010 water year, this gage received a total of 4.4 (2010), 0.9 (2011), and 0.4 (2012) inches of precipitation during May through September.

Commented [UFS2]: Do we have May-Sept 2013?

The annual and seasonal precipitation varied considerably between the years of the sediment plot study from 2010 through 2013 (Figure 18, 19). A second rain gage is located within 2.5 miles of the study area in the Terrace Lakes subdivison. The 2010 water year delivered 40.4 inches, while 2012 delivered 22.7 inches.

Commented [UFS3]: This part is a bit confusing, are these totals for the gage near Scriver? Or for GV?

I was a bit confused about what you said in your email. I believe the WO GARDEN VALLEY 2SE RANGER STATION ID US USBR gage is the one at the ranger station. The other gage "near Scriver" appears to be a NWS coop site… I see it as station D8224 Garden Valley in Mesowest

We should figure out what to call this… because I don't think this gage is in Scriver Cr… Actually appears to be in the Terrace Lakes Subdivision

Commented [UFS4]: Is that day of the water year? Oct-sept

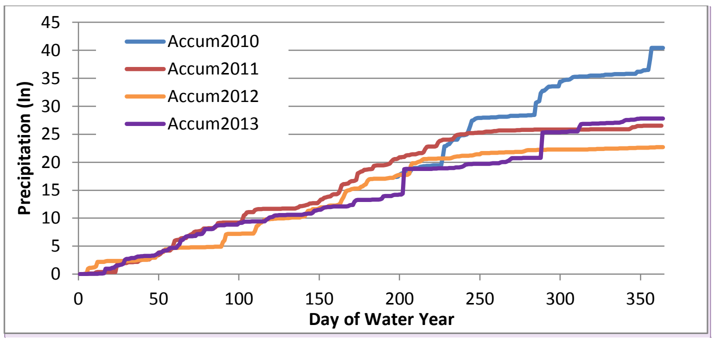


Figure 18. Annual precipitation accumulation by day of the water year for the Terrace Lakes gage during the period of study.

The more significant difference with regard to erosion is the almost complete absence of summer precipitation in the dry years. In the period of May through September 2011 the Terrace Lakes gage received 5 inches and in 2012 only 2.7 inches, compared to 9 inches in 2013 and 21.5 in 2010.

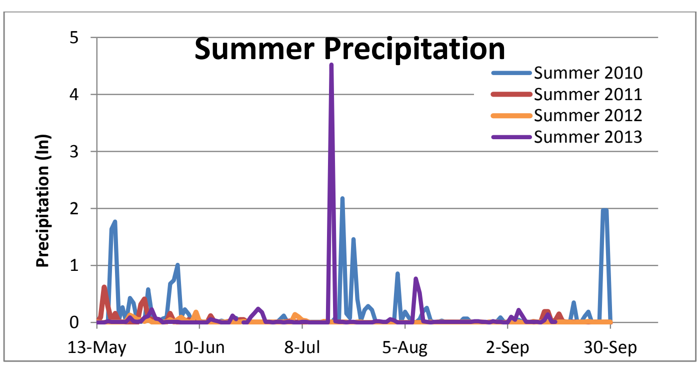


Figure 19. Precipitation received in the spring and summer during the sediment plot study from the Terrace Lakes gage. Note the near absence of summer precipitation in 2011 and 2012.

At the beginning of the study period in 2010, the road was open to traffic and had been used by heavy equipment to conduct an organic matter mastication project. In the winter of 2011 a landslide occurred on the lower portion of the road, effectively excluding most traffic with the exception of ATVs. The road was repaired in 2012. The road did not receive any grading or heavy vehicle traffic during the study.

The average erosion from the group of plots declined over the three years of observation from 226 kg, in 2010 to 43 kg in 2011 to 26 kg in 2012. This declining trend reflects the impact of the initial disturbance of the plot installation, the lack of traffic during the middle portion of the data collection and a lack of intense convective activity at this location during 2011 and 2012.

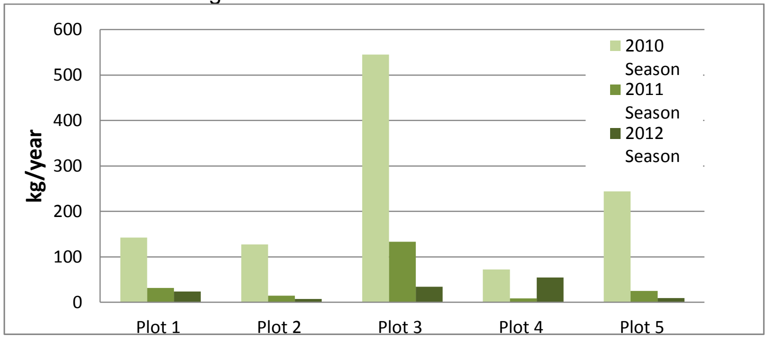


Figure 20. Annual erosion form sediment plots located on Lightning Creek in the Middle Fork of the Payette.

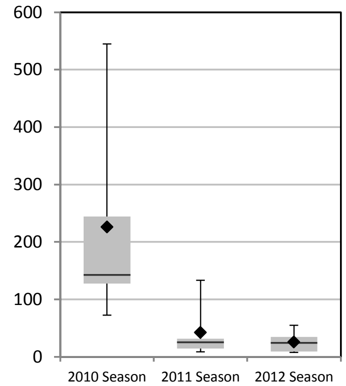


Figure 21. Annual erosion in kilograms at the Lightning Creek plots. Mean value represented by diamonds, the median is represented by the dark line.

Sediment measurements were taken seasonally in October and May during 2012 and 2013 to investigate the seasonal distribution of sediment transport from the road (Figure 22). Previous erosion studies in nearby Silver Creek (Megahan 1983, Megahan and Ketcheson 1996) suggests that snow melt runoff rates are generally too low to result in substantial surface erosion in this area and consequently that summer convective storms and the rare rain on snow event are the most important drivers of sediment production.

While more than 2 years of data are needed to understand the influence of seasonal precipitation patterns on erosion events, this sample suggests that limited erosion occurs in dry summer and that fall and winter runoff should not be discounted as drivers of sediment transport. The largest single sample of erosion occurred at plot 3 during the winter of 2010 and accounted for 48% of the total erosion in the first year and 35% of the total erosion from three years.

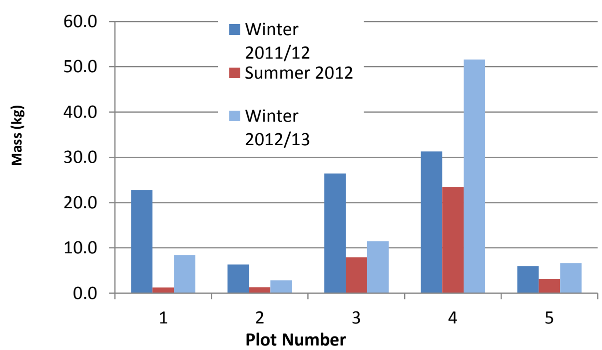


Figure 22. Erosion by season at the Lightning Creek road plots.